Current State and Future Prospects of Development of Assistive Robots for Disabled and Elderly People

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ABSTRACT

When motor functions decline owing to aging or motor disabilities caused by accident or disease, it is preferable that those functions be restored through training and rehabilitation. However, when the recovery of original functions cannot be expected, those functions should be assisted using assistive devices. It is highly desirable not only for people with declined motor functions but also for society that, with assisted motor functions, such people will be able to continue their schoolwork, return to society, and be engaged in jobs and other activities where they can use their abilities.

Caregivers provide assistance of physical functions in accordance with the needs of individual care recipients. However, growing expectations are placed on assistive robots as the solutions to social issues such as "elderly care by the elderly", which causes a significant physical burden on caregivers, and the increasing cost of care. The use of assistive robots is desired because they are preferable to caregivers in some aspects, such as protection of privacy and the maintenance of the independence and dignity of care recipients. Also, disabled and elderly people can, without hesitation, ask for and receive assistance that meets their requirements in detail.

This article provides future prospects of assistive robots and introduces the current state based on the research papers published in journals of academic societies concerned with welfare and medical engineering, products developed by companies, and the contents of the International Home Care and Rehabilitation Exhibitions held in Tokyo in 2016 and 2017. The main focus of this article is motor function support for disabled and elderly people, for example, (1) assistance with walking functions and (2) assistance with upper limb motor functions for those with muscle weakness.

Keywords: development of assistive partner robots, disabled and elderly people and their caregivers, quality of life (QOL)

Introduction

Advancements in science and technology have brought about both significant benefits and numerous problems to all aspects of human society. The benefits, however, are remarkable in medicine and welfare in many countries. In particular, advancements in medical technology have enabled Japan to have the world's highest average life expectancy of 84 years. On the other hand, it is expected that one in three people will be 65 years or older in 2025 while the birthrate will be extremely low. Japan will be facing an aging society with fewer children, which has never been experienced by European countries and the United States[1), 3)]. Faced with this rapid aging of the population combined with a declining birthrate, it is very important to develop and make practical use of technologies and robots that assist the daily living of both disabled and elderly people, including support to enable a purposeful and independent life and the improvement and maintenance of quality of life (QOL), in addition to the development of medical technologies and healthcare devices for maintaining public health[5)] .

For this reason, it is desired to take advantage of all the superior robot technologies in Japan to develop and make practical use of robots designed to help disabled and elderly people live an independent life or to support the care of those people. Such assistive robots will also play a role in reducing the burden on family members and preventing families from being disrupted and broken up when the growing number of disabled and elderly people will require care at home in the future.

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Improvement of QOL of disabled and elderly people and their caregivers

Most of the development of devices and the improvement of environments are intended for the convenience of people with normal functions. When normal functions are lost or damaged because of injuries, diseases, or aging, problems in living in the existing environments and using the existing devices will arise. In other words, whether someone has a disability or not largely depends on the relationship between his/her functions and the environment. It is therefore necessary to realize a comfortable, barrier-free society by improving the physical environment in the area of activity of disabled people and developing useful devices so that neither they nor their caregivers suffer inconvenience or disadvantages in their daily living or social activities. The development and practical use of robots that help disabled and elderly people live independent lives or that support the care of those people are greatly desired, especially in Japan, which will be facing an aging society with fewer children within a few years [2), 4)].

Engineering support for caregiving

The following options are available for providing disabled and elderly people with quality care.

1) Increase the number of caregivers.
2) Develop devices for providing quality care.
3) Develop devices that perform miscellaneous or simple tasks required in caregiving so that select few caregivers can provide quality care in a focused manner.

In Japan, since the enactment of caregiving-related bills, efforts have been made to increase the number of caregivers. However, it is unrealistic to simply increase the number of caregivers along with the growing number of the elderly considering that about 80% of the costs for taking care of disabled people are usually labor costs.

Therefore, under the policy of the Japanese government to provide care for disabled and elderly people at home, first, it is necessary to develop devices that help them live purposeful and independent lives for as long as possible [2), 5)].

Young disabled people and elderly disabled people

In the discussion of various issues related to a high-longevity society, we tend to regard the elderly as disabled people or those who are likely to become disabled. It is true that many issues, such as the normalization of functional decline or disabilities and the promotion of barrier-free environments, are common to both disabled and elderly people. However, although the types of disabilities and the purpose of support are the same, the specific solutions to each issue may differ depending on whether the disabled people are young or old in many cases.

1) Young disabled people: Make positive efforts to overcome the handicap due to their disabilities.
2) Elderly disabled people: Have various mental and physical limitations in making efforts to overcome the disabilities that they develop later in life.

In particular, while young disabled people actively use assistive devices and gain good compensatory skills, it is difficult for people who develop disabilities later in life to gain the same level of compensatory skills even if the types of functional decline or disability are the same. It is therefore necessary to take advantage of advanced technologies to design assistive devices for the elderly, which can be operated with the knowledge they already have[7)].

Users of assistive robots

Healthy aging, despite having diseases and disabilities, is an important subject in the future longevity society. Actually, the proportion of the healthy elderly is increasing yearly. The healthy elderly are the most promising users of assistive robots. Even the healthy elderly are experiencing some degree of functional decline associated with aging. In general, the functional decline observed in most of the elderly should be distinguished from disabilities. Also, the elderly and the people around them regard functional decline as an aging phenomenon, not a disability, even when it affects the daily living of the elderly. For this

reason, the following points should be kept in mind concerning the healthy elderly who are prospective users of assistive robots.

1) They are afflicted with mild functional decline that cannot be regarded as a disability.
2) The decline in mental and physical functions progresses over time.
3) They feel uncomfortable being treated as disabled.
4) They are unwilling to use assistive devices.

When the above points of view are taken into account while developing assistive robots, robots that will be used not only by the healthy elderly but also by a wide range of people regardless of age and gender can be made[7].

Characteristics of assistive robots

Because the assistive robots used for rehabilitation operate in direct contact with disabled and elderly people, they differ substantially from industrial robots in the following four points (robots used in medical practice, medical research, and the field of education are beyond the scope of this article).

1) Assistive robots operate in direct contact with care recipients or patients.
2) Required processes and tasks are not uniform but vary.
3) It is impossible to test or retry the actions of robots.
4) Such robots must be easy to operate for those who are not specialists.

Industrial robots are significantly different from assistive robots in that safety is ensured by separating the work area of humans from that of robots. Thoughtless application of industrial robots to the field of caregiving is very risky. The actions of assistive robots that aid self-supported motions and care motions in daily living are designed to fit the physical functions of humans and are not suitable for industrial robots[7].

Motor function support by assistive robots

The following is an outline of the assistive robots that provide assistance for the walking functions of disabled and elderly people and for the upper limb motor functions of people with muscle weakness.

Walking assist robots

Disabled and elderly people can maintain physical and mental health and improve their QOL through walking.

Once they have difficulty in walking, the amount of exercise in daily living decreases, causing a chain reaction of decline in other physical functions even though the underlying disease may not be severe. Some point out that difficulty in walking may result in a bedridden state. There will be an ever-growing demand for walking assist robots in all medical, caregiving, and rehabilitation areas.

For example, clinical trials using wearable walking assist robots aimed at regaining walking functions in patients after suffering stroke have been initiated at the site of rehabilitation. Also, the devices that allow people to improve balance functions and perform walking training as though they are playing a game are under development[7), 10),11)].

For the elderly, walking is not just a locomotive function. Walking has beneficial effects in keeping the musculoskeletal and circulatory systems healthy. It also enables the elderly to move between patient rooms or go outside the home to maintain social connections, which have positive effects on their cognitive functions. Namely, walking is a basic exercise that enables the elderly to maintain their QOL. With assistive robots, they can walk or participate in rehabilitation while reducing the risk of falling during walking. The introduction of assistive robots will contribute to the development of environments in which the elderly and patients with mild diseases can participate in rehabilitation safely and easily.

Assistive robots for working functions of upper limbs

People with muscle weakness due to disease have difficulty in maintaining posture or have weakness of the upper and lower limbs because of the muscles of the trunk and limbs weaken or atrophy. As the symptoms progress, they will experience difficulties in daily activities including moving about and eating and will require the support of caregivers. Those people feel emotional strain because they are in constant needs of support from others. Also, caring for such people may be a burden on caregivers.

To approach the above issues, upper-limb assistive robots have been studied, aiming at providing support for people with muscle weakness so they may live an independent life and improve their QOL. Upper-limb assistive robots can be classified into the robot-arm type and the wearable type.

Examples of the robot-arm type are robot arms for wheelchairs developed by the National Institute of Advanced Industrial Science and Technology (AIST), SECOM Co., Ltd., and Waseda University. Using the residual functions in the hands or neck, users manipulate a joystick to control a robot arm mounted on a wheelchair or a table. The robot arm serves as a substitute for the user's arm. Such a robot arm is very helpful for people with severe disabilities[10].

Wearable robots are attached to the affected area of patients and directly assist their body motions. Because patients move their hands and play a part in the action, they can maintain their motor functions and exercise their independence.

Wearable robots are further divided into the active-assistive type and the passive-assistive type.

Active-assistive devices contain an actuator (a driving mechanism that converts electrical, hydraulic, or pneumatic energy to translational or rotational motion) to generate assistive power to aid users' motions. These devices allow users a wide variety of actions because users can perform motions beyond their abilities by using these devices.

Passive-assistive devices contain a passive element such as a spring to assist user's motions mainly by mitigating the weight of the user. Because the main feature of passive-assistive devices is to mitigate the weight of the user, they are not suitable for people with only slight residual functions. However, the merits of passive-assistive devices are that these devices do not need an actuator and allow patients to take advantage of the skillful motions of their own body, particularly those of their hands, in performing actions, and that the cost for such devices is low. Passive-assistive devices are suitable for people whose residual muscle strength is sufficient to move their limbs if they are unaffected by their own weight.

Current state of assistive robots[2), 7), 10), 11)]

The urgently required support in daily living is that for toileting, bathing, and locomotion. The need for such support is a topic of long-standing discussion but has not yet been fully satisfied. Efforts are being made in many countries to approach these issues by applying assistive robot technologies, and it is not too much to say that Japan plays a key role in such an approach. Note that, although rehabilitation robots are categorized as medical robots in consideration of their tasks, they are included in the category of assistive robots in the following description.

Rehabilitation

Assistive devices for the elderly with a mild decline in walking functions include walking training systems and walking aids. As described above, locomotion by walking is the basis of an independent life. The difficulties in bathing and toileting, which become a burden to caregivers, can be relieved by providing walking assistance. Walking training systems that are based on the combination of assistive robot technologies and virtual reality technologies as well walking assist systems that are power-assisted and provide appropriate walking assistance to those who have a side-to-side imbalance are currently under development.

Locomotion and transfer

An example of assistive devices for those whose walking functions have severely declined is the step-climbing wheelchair developed using robot technologies. Such wheelchairs now have improved functionalities. For the elderly with serious disability in walking functions, easy-to-use lifts are in practical use in home care. Also, the devices utilizing assistive robot technologies and power assist technologies, such as mobile beds that are aimed at alleviating the labor in transferring a care recipient from a bed to a wheelchair and the specially designed carrier vehicles to carry such beds, have been in practical use in hospitals and care facilities. Ceiling traveling lifts are useful in small houses with many height differences on the floor such as in houses common in Japan.

Beds and around beds

Getting up from bed is the basis of an independent life. To prevent the elderly from becoming bedridden, the easiness of getting up from the bed is important. On the other hand, when the elderly are not able to get out of bed, it is necessary that they feel comfortable spending time on their bed and that caregivers can take care of them smoothly. An electric Gatch bed, which comprises a simple mechatronics system, is a device that assists the first step of transferring care recipients from the bed and is necessary for both promoting the independence of care recipients and facilitating their care. The feature of adjustable height of the bed surface is essential in caregiving.

Studies have been carried out on the assistive robots that lift up a person in bed for transfer from the bed to a stretcher. Currently, attempts are made to handle this issue by using power-assisted stretchers equipped with transfer functions and beds designed with assistive robot technologies, which will enable caregivers to transfer a person from the bed by operating a lever and without touching that person.

Assistance concerning meals

Assistive devices for meals include devices that provide assistance for eating meals and devices that support the preparation of meals (cooking) and cleanup after meals. While home electric appliances will offer superior solutions for the cooking and clean up, eating assistive robots are now under development in order to provide assistance for eating meals. However, most people are negative about eating assistive robots because they feel it is inhuman to use machines to provide assistance for eating meals.

Because many care recipients who need assistance with eating do not have much to look forward to apart from meals, they have a desire to eat on their own will and in the order and at the pace they like. Not only young disabled people but also the elderly who maintain a sense of independence have this desire. This issue cannot be explained by idealism.

When caregivers provide assistance, care recipients may not eat on their own will and at the pace they like because they try not to be rude to caregivers. Also, we should acknowledge the reality that caregivers may provide impersonal assistance when they are busy. For these reasons, there is a great significance in developing eating assistive robots that can be handled not only by young but also by elderly disabled people. Studies on such robots are ongoing.

Toileting

Because toileting is an important activity related to human dignity, the development of toileting assistive devices is essential for maintaining the independence of the elderly and reducing the burden on caregivers. Making practical use of such devices, however, is more difficult than in the case of other types of assistive devices. Toilets with a bidet function, which are in practical use today, largely contribute to labor saving in care after toileting and the good hygiene of private parts. Bidet toilets with more sophisticated features or those that are easier to use will be developed in the future.

Waist-deep toilet booths with a bidet function mainly focusing on the hygiene of private parts that tend to be unsanitary have been in practical use. Such toilet booths are toileting assistive devices based on mechatronics technology. Also, toilets with lifting functions that assist in sitting on and getting up from a toilet seat are designed utilizing simple mechatronics technologies and offer great benefits.

Bathing

The Japanese bathing style is to soak to the neck in a bathtub to warm the body. Getting in and out of such a bathtub is a major hurdle for the elderly and disabled people. It not only causes a physical burden on caregivers but also poses a risk of falling for both caregivers and care recipients. To solve this issue, a wide variety of lifts, from a simple one for use at home to a large-scale apparatus for use at care facilities, have been developed in order to move care recipients into and out of a bathtub.

The bathing style described above is unique to Japan and therefore the burden of bathing assistance matters little in countries where taking a shower is more common than using a bathtub. Taking account of these facts, showering should be the main function of bathing assistive devices. Also, the devices for assisting in Japanese-style bathing should be

considered as devices that provide emotional support, not the devices that support an independent life of care recipients or reduce the burden of caregivers.

Practical use and future prospects

Caregivers provide assistance of physical functions in accordance with the needs of individual care recipients. However, growing expectations are placed on assistive robots as the solutions to social issues such as "elderly care by the elderly", which causes a significant physical burden on caregivers, and the increasing cost of care. The use of assistive robots is desired because they are preferable to caregivers in some aspects, such as protection of privacy and the maintenance of the independence and dignity of care recipients. Also, disabled and elderly people can, without hesitation, ask for and receive assistance that meets their requirements in detail.

Because the use of assistive devices is closely connected to daily living, one need not be an expert to generate various ideas regarding such devices. However, turning an idea into a useful device is difficult in many cases even if it is possible in theory. Actually, studies as well as various demonstrations on the assistive care robots for bedridden disabled people were carried out in Japan in the 1990s but such robots have not yet reached practical use. It is necessary to recognize that demonstrations and practical use are two different things. The situation is the same worldwide.

With the advent of a longevity society, there is a need in Japan to develop assistive care robots that are suitable for practical use. A robot like Astroboy will solve many problems at once, but the longevity society will not wait for the creation of such a robot. Therefore, we must do everything possible to solve problems one by one even though the features of the robots that we develop are not very sophisticated. For example, one way is to separately realize the aspects of assistive robots concerning heavy physical work and the aspects concerning emotional support. Even the development of assistive robots at such a level promotes the provision of support to disabled and elderly people at an early time. Also, these processes are significant as the basic stage in the development of ideal assistive robots.

In 2007, Japan entered the super-aging society characterized with a sharp decline in the working-age population and an increase in the elderly population not in the labor force. In order to maintain mental and economic vitality, there is an urgent need to develop devices that will help the elderly to live independent lives. Also, considering the need of long-term care of the elderly, assistive devices should be developed from the viewpoint of caregivers rather than that of care recipients. To sustain the prosperity of such a super-aging society, an urgent task is to put a variety of assistive devices into practical use so that people can use those devices in a manner similar to the use of home electric appliances. Because most of those devices are operated by aged wives or housewives living with the elderly, those devices must be easy to use for such women. Safety and ease of use without the need for any special training are important factors in the development of those devices.

Conclusions

Assistive devices are helpful when lifting something up. To introduce assistive devices at sites of care, such devices must be developed from the viewpoint of users, namely, the disabled and elderly people, focusing on safety, user friendliness, and improved

compatibility with the human body. At the same time, studies on the technologies of precise measurement or control of the status of users, history management, and database development, which are the specialty of robots, are also required.

It is our desire that a bright future be achieved through the development of assistive partner robots having both intelligence to help humans and friendliness toward humans. Even difficult tasks will become possible when humans operate robots. For example, a family member living far away from an elderly person will be able to tell a robot to open the curtains or to fetch a glass of water for the elderly person. Our goal is to realize a society where everyone enjoys a happy life.

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