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Telepresence robots for medical and homecare applications

Abstract

Over the past few decades, robotics has made tremendous progress in saving, protecting, and improving human lives, and is now adopted across a broad range of applications in medicine and homecare services. While technologies are developed at a rapid pace, people are expecting robots to be part of their lives in a more natural way. Among the wide variety of robots, telepresence robots, which allow the user to experience the virtual presence in another place, offer the potential to meet this rising demand better and is thus of great concern. This section will explore the up-to-date research findings and industry practices in telepresence robots for medical and homecare applications. Moreover, the key contributing factors to the success of telepresence robots will be discussed as well to address the future trends and opportunities.

Keywords: telepresence robots, medical telepresence, homecare telepresence, user acceptance

1. Robotics in medicine and homecare

Tracing back to the first use of the term "robot" by Čapek in his play entitled "Rossum's Universal Robots" in 1920, robots were originally regarded as the artificial people produced to work as servants. From then on, the term "robot" began to be widely adopted to describe the human-like machines that assist human beings. In the beginning, most robots were developed to facilitate repetitive works for the performance of industrial applications [Robot Institute of America, 1979]. With further advancement of robotics, more people realized the great potential of robots. Hence, robots were also expected to enrich the daily lives of human beings more naturally and directly by performing all kinds of services [International federation of Robotics, 1998]. Nowadays, robots are generally categorized by the application fields into two main types: industrial robots and service robots. More specifically, either category of robots can include both autonomous and teleoperated robots, depending on how the robots are controlled.

Robots have the advantages of high precision, strong consistency and reliable stability. Thus, in the field of medical application, the use of robots exactly helps to overcome the technical limitations of conventional surgery. The first robot-assisted surgery was performed in 1985. The Unimation Puma 200 robot, which was equipped with a computerized tomographic scanner and a probe guide, was used for stereotactic brain surgery [Kwoh et al., 1988]. With the advancement of technologies, medical robotics was further developed to extend human capabilities in surgery. Intuitive Surgical [2010] introduced the da Vinci® Surgical System with advanced supersensory for telepresence. By integrating a surgeon's console, a patient-side cart with robotic arms, and a high-performance vision system, the surgeon's hand movements can be seamlessly translated into precise and minimally invasive movements. In addition, robots also play an increasingly important role in modern medicine, ranging from training the medical and nursing staff, assisting diagnosis, to facilitating patients' rehabilitation and care. Some medical schools make use of Human Patient Simulator (HPS), a robot that mimic human's feelings of pain or discomfort, to help the soon-to-be doctors and nurses prepare to treat real patients [METI, 2011]. Besides, the InTouch Health [2011] developed a mobile robot called RP-7 to enable the physician to be remotely present for diagnosis. It helps to remove time and distance barriers and effectively extend the physician's reach to manage patient care. In this way, patients feel more satisfied because physicians seem to spend more time with them [Gerrard et al., 2010]. Further, Kaczmarski and Granosik [2011] presented the rehabilitation robot RRH1. By helping the patients replay trained exercises such as hip and knee flexion/extension and leg abduction/adduction, the rehabilitation for the lower extremities can be easily performed with safety. Moreover, robotic assistive limbs which enhance the caregiver's strength for patient handling [Satoh et al., 2009] and the robotic wheelchair with the function of automatic navigation [Pineau and Atrash, 2007] can provide much help in homecare. Toward a higher quality of life, interactive robots serve as a new type of communication tool for medical or homecare use. Seal robot Paro is an example of robot-assisted therapy for improving mental health [Wada et al., 2008].

As shown in Table 1, the robots for medical and homecare applications are summarized according to the participants and activities involved. Generally speaking, the use of robots has made revolutionary changes by greatly helping the medical community in various ways to save patients, improve quality of life and prevent health problems.

Table 1. Categories of robots for medical and homecare applications

ACTIVITIES	PARTICIPANTS						
	medical staff	nursing staff	patient	caregiver	caretaker	family & friends	others
training	L	L					
surgery	F, I	F, I	F, I				
diagnosis	D		D				
consultation	C, D	C, D, K			C, D, K		
monitoring	D	C, D	C, D	C, G	C, G, J, M	C, G, J, M	
rehabilitation	H, N	H, N	H, N				
therapy		A	A, R, U, V		A, R, U, V		
assistance		E	E, O, P, Q	E	E, O, P, Q	E	
communication	C	C		J, M, Q, T	B, C, J, M, Q, T	B, C, J, M, Q, T	
pharmacy							W
prosthetics	X	X	X				

A: [Böhm and Gruber, 2010], B: [Breazeal, 2000], C: [Brière et al., 2009], D: [Gerrard et al., 2010], E: [Helal and Abdulrazak: 2006], F: [Intuitive Surgical, 2010], G: [iRobot Corporation, 2011], H: [Kaczmarski and Granosik, 2011], I: [Kwoh et al., 1988], J: [Lu et al., 2011], K: [Luo et al., 2009], L: [METI, 2011], M: [Michaud et al., 2008], N: [Mouri, 2009], O: [Mukai et al., 2008], P: [Pineau and Atrash, 2007], Q: [Powers and Kiesler, 2006], R: [Saito et al., 2003], S: [Satoh et al., 2009], T: [Tsai et al., 2006], U: [Wada and Shibata, 2007], V: [Wada et al., 2008], W: [Intelligent Hospital Systems, 2011], X: [Tsoli and Jenkins, 2011].

Among the wide variety of robots, telepresence robots do have the benefits of providing closer connections between the two ends of users, which is often emphasized and demanded in health care. Thus, in the next section, recent advances of telepresence robots for medical and homecare applications will then be introduced for better understanding. Subsequently, key factors contributing to the success of telepresence robots will be further discussed to reveal the real needs from the users' perspective.

2. Recent advances of telepresence robots for medicine and homecare

As Section 1 introduces, robots for medical and homecare applications can assist human beings across a wide range of activities. Considering the special needs with regard to telepresence, some up-to-date research findings and industry practices are reviewed in the following context for a comprehensive overview.

2.1 Surgery, diagnosis and consultation

As mentioned in the previous section, the da Vinci® Surgical System makes use of telepresence technology to enable surgeons to perform delicate and complex operations with increased vision, precision, dexterity and control [Intuitive Surgical, 2010]. In addition to serving as the assistant on the first line of medical services, telepresence robots can assist the doctors in diagnosis and consultation as well. InTouch Health [2011] released the mobile robot RP-7 that enables the physician to extend their reach to manage health care by making themselves remotely present near the patients. The robot doctor also allows direct connection to Class II medical devices, such as electronic stethoscopes, otoscopes and ultrasound, for transmitting medical data to the remote physician. Medical personnel can thus discuss treatment plans and interact with patients remotely, which helps improve the efficiency of medical diagnosis and treatment for non-life threatening emergencies. In order to expand the range of use, Brière et al. [2009] presented Telerobot, an in-home telehealth robot for clinical application. Telerobot is controlled using two screens. One is for the clinical information system, and the other displays the control interface with a virtual joystick and the video stream. In addition, Luo et al. [2009] also developed a telemedicine robot that allows the medical staff from long distance to provide consultation for the elderly people living at home. Combined with the wearable sensors, the robot will detect the emergencies such as falls and immediately inform the family members.

2.2 Rehabilitation and therapy

Telepresence helps extend not only human vision and hearing but also the sense of touch, which is important for physical rehabilitation. Mouri et al. [2009] proposed a novel hand telerehabilitation system comprising a hand rehabilitation support system for the patient, an anthropomorphic robot hand for the therapist, and a remote monitoring system for diagnosing the degree of recovery. The therapist applies the force to the robot hand, and the force is then transmitted to the patient via the rehabilitation support system. This makes both participants experience the face-to-face rehabilitation even though they are in fact far way from each other. Besides, the remote monitoring system provides quantitative data in real time, resulting in higher efficiency of treatments. Psychologically, therapeutic robots based on telepresence also have the potential for improving people’s mental health. The EU project IROMEC (Interactive RObotic social MEdiators as Companions) developed a therapeutic robot for children with minor motor disabilities or communication deficiencies. Since autonomous robots pose the particular hazard to handicapped children who are not able to react properly to a moving robot, the IROMEC robot makes use of telepresence and is controlled by the remote therapeutic personnel to play with the children by following them or dancing [Böhm and Gruber, 2010].

2.3. Monitoring and assistance

The use of a robot can be an alternative to locating cameras everywhere in the house. Instead of having the feeling of being watched all the time, the robot will only look around when there is any possible risk detected. iRobot LE was developed for people to use it as a security guard to monitor house as if the remote user actually goes around in the home environment. With the telepresence capability, it gives the remote user access of not only security in monitoring house or investigating household, but also checking the conditions of the elderly people living alone [iRobot Corporation, 2011]. To be more active while living with people, telepresence robots can provide assistance in various ways. By extending the concept of smart homes, Helal and Abdulrazak [2006] proposed the development of TeCaRob, a telecare robot, to provide physical assistance for people with special needs in the health care center. Caregivers stay in the remote operation center and wait for the senior people's needs. The robots can assist the elderly in many ways such as transferring and moving them, feeding them, giving medications, or doing some tasks for them.

2.4 Communication

Derived from the idea of a mobile robot with videophone embedded, Michaud et al. [2008] presented a teleoperated robot with wheels. Telepresence is provided for both ends with auditory and visual information. But the feeling of "staying with the person at the same place" is however limited due to the machine-like appearance. Tsai et al., [2006] developed a telepresence robot for interpersonal communication (TRIC) for the daily use of the elderly in the home environment. With the human-like appearance, the robot can better serve as the avatar of the children or grandchildren for expressing their care. Given high mobility by means of omnidirectional wheels and ultrasonic sensors, it is able to move in all directions, turn around and avoid collisions with the environment. Toward a better convenience of home use, it was then redesigned into a compact size with more plentiful presentation of the remote user's emotions and feelings, by means of eye contact, facial expression, and body language. The physical face-to-face interaction among people can be thus rebuilt to provide a more natural communication as if both users are being together with each other [Lu et al., 2011].

3. Key factors contributing to the success of telepresence robots

Although technologies have made great contribution to the development of telepresence robots, the most important concern remains the user acceptance. In other words, since a telepresence robot is intended to serve as the avatar or agent of a human for interacting with the environment or other people, it is necessary to provide the realistic sense of “being there” for the remote controller, as well as the experience of “acting like a real person” for the local user who stays with the robot. Broadbent et al. [2009] discussed the user acceptance of social robots in terms of robot factors and human factors. The two categories provide totally different views for the requirements of a robot. The former focuses on the functions or utility of the robot, while the latter highlights the relationships between the user characteristics and the feelings toward the robot. Based on this concept, the key affecting factors to the success of telepresence robots are further discussed and summarized hereafter. These findings can provide practical guidelines for researchers, professionals and practitioners in this field.

3.1 Robot factors of acceptance

Robots are regarded as the products of technology and scientific innovation. In addition to the advanced functions that benefit human beings, how the robot interacts with people actually influences the user acceptance more greatly. This is especially critical for telepresence robots, in which the feeling of presence is highlighted. It is not only about making the remote user experience exactly what the robot perceives and where it travels, but also about whether the local user considers the robot as a realistic one. Generally, these robot factors include its anthropomorphism, physical characteristics, and personality. As the robot acts or reacts more naturally as real humans do, the user will show greater interest and be more willing to interact with it.

(1) <u>Anthropomorphism</u>

Anthropomorphism, or human likeness, refers to projecting human characteristics to non-human animals or non-living things. Generally, it involves various attributes of the robot, such as appearance, facial expression, and body motion. As the level of anthropomorphism goes higher, the interaction performance can be further improved [Li et al., 2010]. For example, Goetz et al. [2003] indicated that the appearance of a robot influences people’s perceptions of a robot, as well as their willingness to follow the instructions given by the robot. However, the humanoid robots are not always the preferred ones. As shown in the 2000-people survey conducted by Arras and Cerqui [2005], only 19% prefer a humanoid appearance. In fact, the user acceptance depends on whether the level of anthropomorphism matches the sociability required in the jobs. More specifically, people would prefer human-like robots as office clerk or hospital message carrier, while machine-like robots are expected to be lab assistant, inspector, or guardian [Goetz et al., 2003]. Considering the task involved, people also tend to cooperate with human-like robots rather than machine-like robots [Hinds et al., 2004]. Further, the user perception also relates to the dimension of the robot's head and its facial expression. Powers and Kiesler [2006] found that a shorter chin contributes to the perception of higher sociability and higher intentions to follow the robot's medical advice. In addition, large smiles with slow transitions are seen as more appealing by the users [Powers et al., 2005].

(2) Physical characteristics

As a robot becomes closer to a real human, the physical characteristics such as gender, age, height and weight will then have impacts on the user acceptance. Powers et al. [2005] reported that participants said fewer words to the female robot than to the male robot in a human-robot dialogue. This phenomenon might be explained by the traditional role stereotypes. Besides, the age of a robot can influence its role that people experience. For example, if the robot has an adult humanoid appearance, people will expect it to be able to converse more naturally than the robot with a younger appearance [Breazeal, 2000]. Moreover, the preference of the robot size is determined by the tasks it involves. Robots for home use are expected to have a smaller size [Giuliani et al., 2005], whereas robots for patient handling require a larger size to support the weight and increase user's confidence [Mukai et al., 2008].

(3) Personality

In addition to the physical characteristics, the personality of a robot, including its emotional, attitudinal, and behavioral response patterns, also plays an important role in user acceptance. For an efficient use, it has to match either the user's characteristics or its own role. Obviously, a caring and empathic personality will encourage interaction between the user and the robot [Bickmore and Picard, 2004]. Besides, Heerink et al. [2006] reported that a more socially communicative robot would be more likely to be accepted as a conversational partner. Further, perceptions of knowledge and sociability were found to be able to change people's intention to follow the robot's advice [Powers and Kiesler, 2006]. Moreover, Ţăpuş et al. [2007] demonstrated that a robot's adaptability to the user's personality is important for user improvements of rehabilitation exercises.

3.2 Human factors of acceptance

There is a great diversity of human beings. People are with quite different physical characteristics, backgrounds and experiences. In addition to the robot factors, the user acceptance is also affected by these many human factors. For telepresence robots, from the remote user's point of view, the feeling of presence may vary among different people even though the condition remains the same. As for the local user, one unique activity that the robot performs may produce different perception or response among people. Thus, it is necessary to investigate the causes and consequences of these factors for a better robot design.

(1) Physical characteristics

Arras and Cerqui [2005] investigated the relationship between age and the willingness of living on a daily basis with robots. The results show that young adults tend to give more positive responses than older adults (over the age of 65). Nevertheless, under the assumption that one is with impaired mobility and is unable to handle the daily activities, the older adults will be more willing to accept a robot to help them gain independence. Besides, gender of the user also makes difference. While interacting with a robot, males wonder more about the technical aspects, whereas females are more interested in its name [Taggart et al., 2005]. Further, in Nomura et al.'s study [2008], the experimental results imply a gender difference in relationships between negative attitudes and anxiety, and behavior toward robots. Among people who have high negative attitudes and anxiety toward interaction with robots, males tend to avoid touching or talking with robots, while females still talk to the robot but not engage in much self-disclosure with it.

(2) Backgrounds and experiences

With different background and experiences, people may have varied attitudes toward technologies or robots. Giuliani et al. [2005] reported that as the educational level gets higher, one will try to make connections with technological solutions more frequently. Besides, lack of familiarity with technologies can be a major reason for people feeling uncertain about robots [Dijkers, 1991). As people stay longer with a robot, it will also change their attitudes toward it. Over a two-month study conducted by Wada and Shibata [2007], residents in a care center finally developed much better personal relationships with the therapy robot. Moreover, cultural differences also make impacts on people's attitudes towards robots. Bartneck et al. [2006] reported that Americans were more positive in their attitudes towards robots than other cultures across Asia, Europe and North America. Differences were also found between European groups, in which French-speaking people would accept a human-like robot more than Germans did [Arras and Cerqui, 2005].

(3) Roles and needs

People will have different attitudes toward robots while they are playing different roles. For example, robots are generally accepted by patients and their families as a powerful assistant. However, robots often produce negative attitudes among the medical and nursing staff. Wasen [2005] indicated that robots sometimes make assistant surgeons feel isolated in surgery, and they are also annoyed because of the difficulty in moving the robots around. As for nurses' reactions, many of them were distrustful of the technology, worrying that their job security was threatened [Novek et al., 2000], as well as feeling stressed while working with a robot [Saito et al., 2003].

3.3 Summary

From the robot's perspective, since a telepresence robot is intended to serve as an avatar of a real human, it is expected to look and act like human beings do. Besides, in order to meet the local user's expectations, it would be better to make the robot's physical characteristics or personality match its own role or those of the remote controller. From the user's perspective, human-centered design is definitely critical to the success of a telepresence robot. Once the real demands can be explored and realized, telepresence robots will eventually enter our lives as new roles for modern medicine and homecare.

4. Concluding remarks

Robots have greatly changed people's lives by contributing to the advancement of modern medicine and healthcare. Telepresence especially assists in realizing the remote medicine and healthcare with realistic senses and feedbacks. Nevertheless, no matter how technologies are accelerating the development of robotics, the most important thing is meeting the real demands of human beings. From both robot and human perspectives, the principle of using telepresence robots is to rebuild the face-to-face experiences among people in medical treatment or homecare services. Besides, customized considerations can further improve the acceptance for a wide range of users. Unlike autonomous robots, telepresence robots are never expected to totally take over the medical and nursing staff's jobs. Instead, they cooperate with the professionals toward a higher quality without borders of time and distance. As long as people have needs for medical and homecare services, plenty of opportunities will be there for telepresence robots.

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