

Assistive Social Robots for People with Special needs

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Abstract—An increasing number of elderly people leads to demand for social robots to support health care and independent life. An overview of various potential applications of social robots is provided in this paper. In addition, the latest research progress in our institute is presented, i.e., multi-party interaction, gesture recognition, affective computing, and attention capture. All the research and applications demonstrate that social robots are good assistive robots for people with special needs.

I. INTRODUCTION

The report of World Health Organization estimate that 21.2% of population will be aged 60 and older by the year 2050, which is nearly 3 times than that in the year 1980, as shown in Figure 1. In addition, cognitive ability of nearly one third of population aged more than 85 would decline [1]. In fact, many industrial countries are meeting or will meet such aging times, such as Japan, Germany, USA, and China [2]. In order to make up for the inadequacy of nurse and caregiver personnel, more and more novel technical solutions are proposed recently [3], [4].

Social robots can improve the social interaction, companionship and physical condition of the aged and disabled, and thus attract more and more attention [3], [5]. They can help the elderly and disabled people to live independently [3]. For instance, Figure 2 shows a social scenario about that a real person and two social robots interact with each other as peer-to-peer companions. The target audiences of these novel technologies are elderly and frail people, physically disabled people, psychically disabled people, chronic patients, severely restrained people, and certain occupations or ordinary being [5].

By reviewing the literature [4], [6]–[57], some significant functions that the existing social robots possess (see Figure 3) are summarized as below:

- Some social robots possess the capability of telecommunication and interaction. With such a function, the users can keep in touch with their family members and friends.
- Some social robots possess the capability of household services. With the help of this kind of social robots, elderly and frail persons' daily life would be improved a lot. For instance, the social robots can remind the users' some important issues. The robots have physical bodies, and thus they can act on the physical world. For instance, they can hold the drink, assistive cooking, etc.
- Some social robots possess the capability of mobile manipulation, data collection, surveillance and smart processing.
- Some social robots can reduce stress and stimulate interaction.
- Some social robots are used for entertainment.
- Some social robots are used for education.

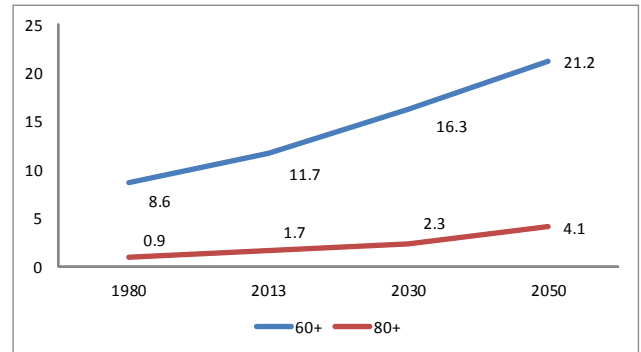


Fig. 1. Population aged 60 years and 80 years in the world, 1980-2050 [58].

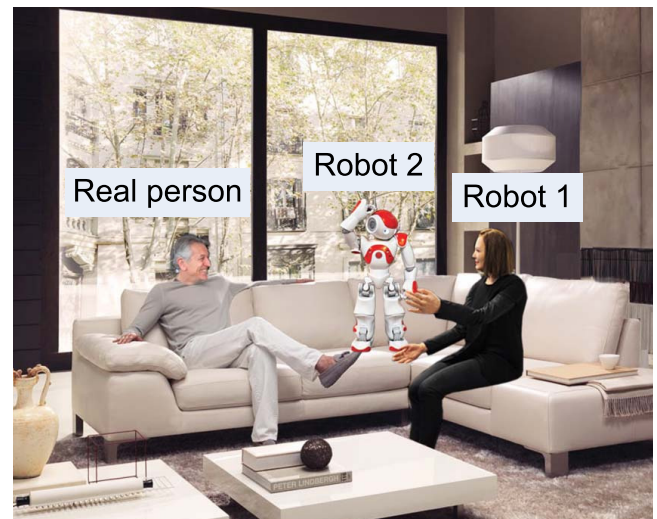


Fig. 2. Social robots and a real person interact all together.

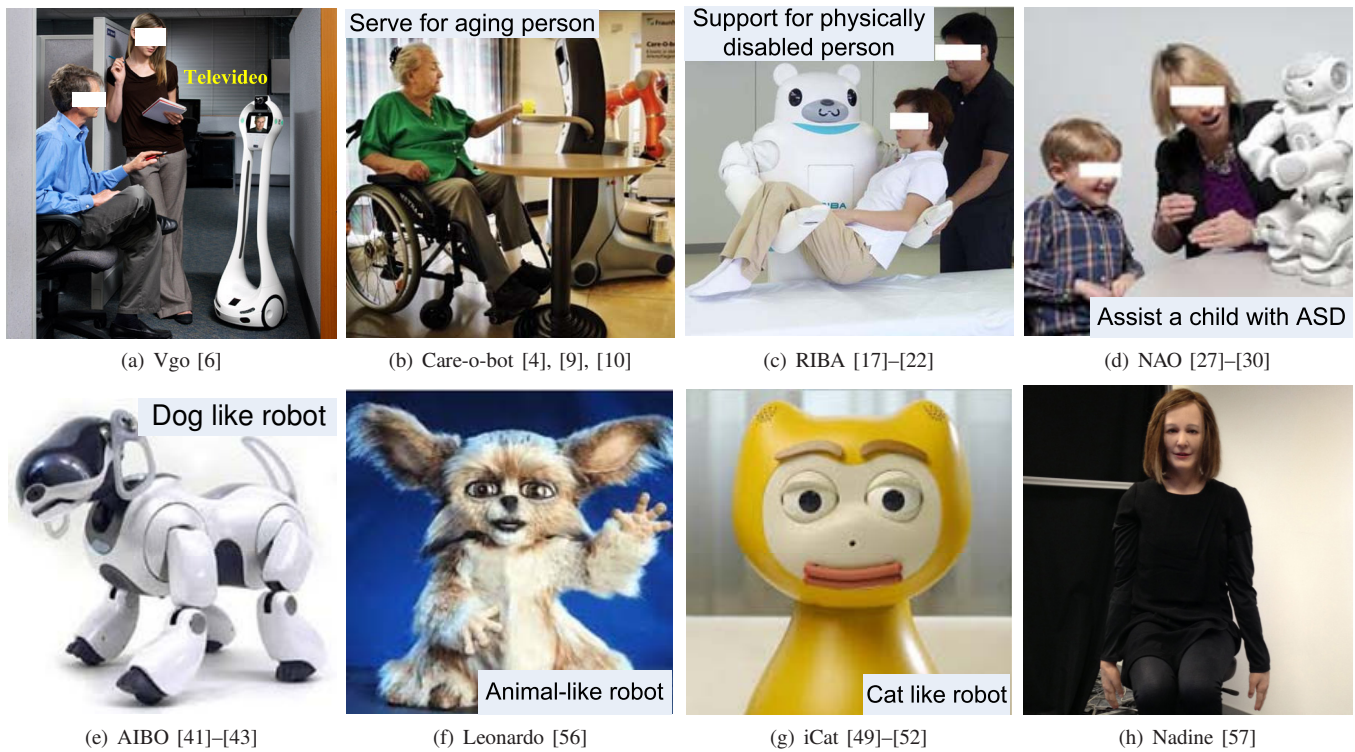


Fig. 3. Social robots applied in various aspects for improving quality of people's life.

II. APPLICATION FIELDS

As shown in figure 3, social robots are mainly applied to five areas, such as telepresence support (see Figure 3(a)), household services for elderly and frail persons (see Figure 3(b)), supports for physically disabled persons (see Figure 3(c)), services for psychically disabled persons (see Figure 3(d)), affording people entertainment and pleasure (see Figure 3(e)), and research platforms (see Figure 3(f)-(h)).

A. Telepresence Support

Face-to-face interaction can transmit some important social cues during conversation, which can contribute to feelings of engagement, trust, persuasion etc [8]. Telepresence should make the participant believe/feel herself to be present at a location other than where she really is [59]. Most existing telepresence robots (e.g., the Vgo robot in Figure 3(a)) are used for telecommunication and remote presence with independent mobile platform [60]. It allows a teleoperator to communicate with others at a distant location. Researchers also develop some novel robots with the capability of autonomous and semi-autonomous navigation behaviors [6]. Telepresence agents are suitable for a range of applications, such as daily communication, work environment, health care, education, and aging [60].

B. Household Services for Elderly and Frail Persons

As the ageing population continues to grow, a lot of researchers and engineers are attracted by socially assistive robots [3], [5]. The researchers try to design social robots to support people to live independently at their own home. Compared with pure task-oriented agents, social agents are more

respected, favored, and trusted. Recently, some researchers try to integrate the task-centered robot with social characters [8]. It is better that if the robot can provide both physical service and emotional support. The robotics researchers expect that the robots can have the capability of communication in a natural way (e.g., speaking, body postures, and facial expression, et al.), fetching and delivery items, and assisting the individuals with daily living activities (e.g., drinking, dressing, and taking medication) [2].

Care-O-bot™, a mobile social robot, integrates fetching, carrying capabilities and social features [4]. To help the elderly people with mild cognitive impairment to live independently at their own home, CompanionAble robot is developed for detection, tracking and user-centered navigation [61]. It can remind the user to do some cognitive stimulation exercises, greet the users, et al. The above robots can increase personal independence, and improve the life quality. NurseBot Pearl robot focuses on reminding and guiding [23]–[26].

C. Support for Physically Disabled Persons

Another important application of social robots is to help the physically disabled persons, such as post-stroke rehabilitation. Stroke may cause loss of movement. One strenuous task is to move a long-term bedridden patient from one place to another [17]–[22]. In order to complete such a work, the RIBA robot was developed by the RIKEN-TRI Collaboration Center in 2009 [17]. Physically disabled persons need motivation, encouragement, guidance, supervision and administering in the process of their rehabilitation [2], [62], [63]. During this period, social robots can offer emotional support, but not to replace the original rehabilitation therapy. Social robots can guide the patients to recover their bodies, and help them boost

TABLE I. AN OVERVIEW OF SOCIAL ROBOTS APPEARING IN THE LITERATURE.

Robot name	Functions	Project/Sponsor	Selected references
VGo	Replicate person in a distant location	VGo Communications	[6]
Care-O-bot	has the capability to perform fetch and carry	Fraunhofer IPA	[4], [9], [10]
RIBA	Can Lift a Human	Grant-in-Aid for Scientific Research from Japan Society for the Promotion of Science	[17]–[22]
NAO	Humanoid robot	Aldebaran-Robotics	[27]–[30]
Nexi	Human-like	National Science Foundation Research Grants BCS	[44], [45]
Kismet	emotion	ONR and DARPA under MUM N00014-95-1-0600, and by DARPA under contract DABT 63-99-1-0012	[53]–[55]
PEBBLES	Providing Education by Bringing Learning Environments to Students	The PEBBLES and NSERC (#184220 – 01)	[7]
CompanionAble	can fetch and carry	The European FP7 project CompanionAble (project duration 2008-12)	[11]–[13]
USC robot	influence the users intrinsic motivation to perform the task	National Science Foundation under Grants IIS-0713697, CNS-0709296, and IIS-1117279	[14]–[16]
QRIO	Human-like	Sony	[36]–[40]
Simon	Human-like	Socially Intelligent Machines Lab (Designed by Carla Diana and Meka Robotics)	[46]–[48]
Leonardo	emotion	Personal Robots Group	[56]
MeBot	Communicates with expressive gestures	the Digital Life and Things That Think consortia	[8]
Nursebot	Can Lift a Human	Information Technology Research (ITR) Program (Grant No. 0085796)	[23]–[26]
Paro	Seal-like	Intelligent System Co., Ltd	[31]–[35]
AIBO	Dog-like	Sony	[41]–[43]
iCat	Cat-like	EU FP7 ICT-215554 project LIREC German Research Foundation (DFG) within the SFB 673 'Alignment in Communication' Project C2	[49]–[52]
Nadine robot	Human-like	Singapore National Research Foundation under its International Research Centre @Singapore Funding Initiative and administered by the IDM Programme Office	[57]

the morale when they are discouraged [2]. For instance, the robot can be used to assist, encourage, and supervise a patient but without interventional therapy.

D. Service for Psychically Disabled Persons

Social robots can also provide support for the psychically disabled person [2]. An individual with cognitive disability may need a coach or a companion. The patient requires effective and special education and therapy to train the brain and improve the daily functions. For instance, if a child is with autism spectrum disorder (ASD), he will have difficulties in social-communication and social interaction [64]. Recent study shows that early intervention is useful for the children to improve the performance [2]. Social robots thus get much more attention because they can improve the communication ability of the children affected by ASD [27]–[30], [65], [66]. Life-like robots can help the children with ASD to reduce their stress, which can improve their desire of communication [31], [32], [34], [67]. The research of social robots related to ASD or cognitive impairment is more about teaching social skills [65], reducing stress [31], [34], and providing relatively objective and quantitative diagnosis [68]. With anthropomorphic characteristics and human-like expression, humanoid social robots can teach the individuals with autism some social skills incrementally [27]–[30], [65].

Animal-like social robots can effectively reduce stress and depression, and make users happy [31], [34], [67]. Some research shows that the elderly users smiled more and become more and more willing to cooperate with their caregivers [2]. That is to say, the robots help the elderly users to improve their emotion, and keep a good state. It is worth pointing out that social robots can help to diagnose cognitive illness objectively because the experimental setting can be repeatable [68].

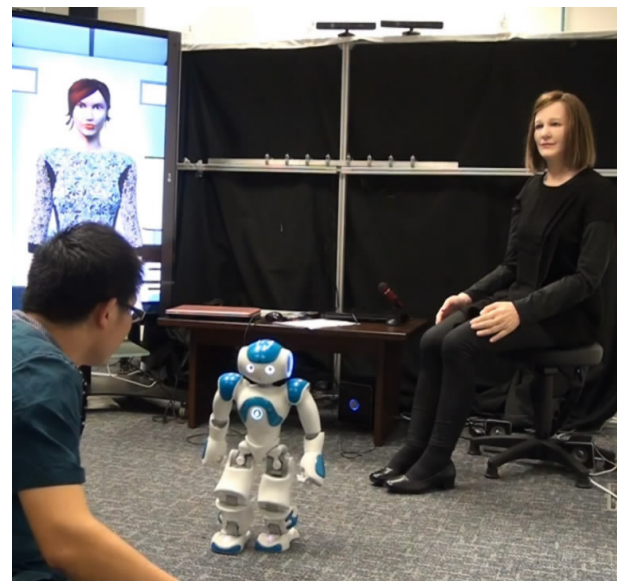


Fig. 4. Interaction among multiple robots, a virtual human, and a real person.

E. Providing Entertainment and Pleasure

Entertainment is another application of social robots. Individuals' life can be enjoyable by using social robots [36], [37]. Some marketing studies show that pet-type robots can make users happy [41]. In general, the social robots used for entertainment possess some special capabilities. For instance, AIBO robot can dance and sing [42], [43]. Jean et al. present a multimodal interactive robot, which can sing, cry, laugh and look around, correspondent to different events.

III. LATEST RESEARCH ON SOCIAL ROBOTS AND VIRTUAL HUMANS

The Nadine robot (see Figure 3(h)) is a humanoid robot in our institute. The robot has been manufactured by Kokoro's

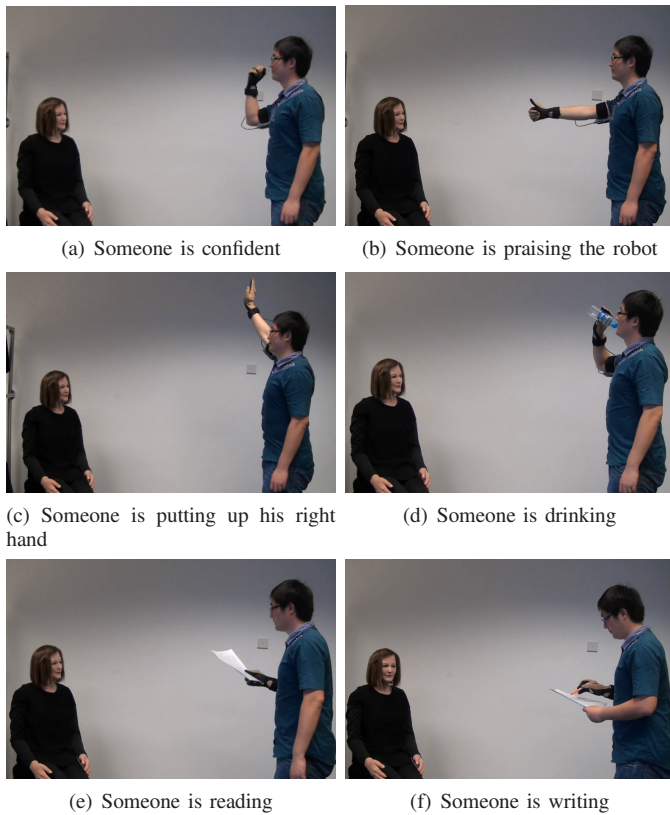


Fig. 5. Human gestures recognized by a social robot.

Actroid technology¹. It has two arms, and facial expressions. This robot has a realistic artificial skin and is able to display some realistic facial and body expressions. The robot has a total of 26 DOF for facial expressions and upper body movements. The Nadine robot can speak, display emotions and natural gestures. This makes it ideal for the study of Human-Robot Interaction². To date, our research mainly involves in social communication [69], gesture recognition [70], fall down detection, affective computing, attention capture.

A. Interaction Among Multiple Social Robots, Virtual human and Real person

Multiple robots may bring more pleasure to the user since different robots have different abilities and can finish their tasks. In addition, the membership can also make them closer with humans. As shown in Figure 4, the scenario is that there is a child, a mum and a virtual human. The agents firstly introduce themselves independently, and then they show their capabilities. The virtual human can display all the gestures that the robot can. The robot can display some impressive behaviors since she has a physical and realistic body and possesses the capability of human-like motion generator. The NAO robot can take a photo and submit it in his facebook³, which usually bring much pleasure to the users. In addition, the user can also add NAO as his friend via internet. This experiment shows that competitive game and multiple agents can bring more pleasure and better user experience.

¹<http://www.kokoro-dreams.co.jp/english/>

²<http://imi.ntu.edu.sg/IMIRResearch/Pages/facilities.aspx>

³<https://www.facebook.com/nao.nao.359>

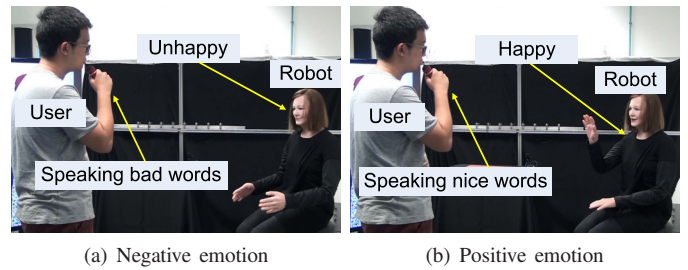


Fig. 6. Emotional reactions of a humanoid robot stimulated by different social cues.

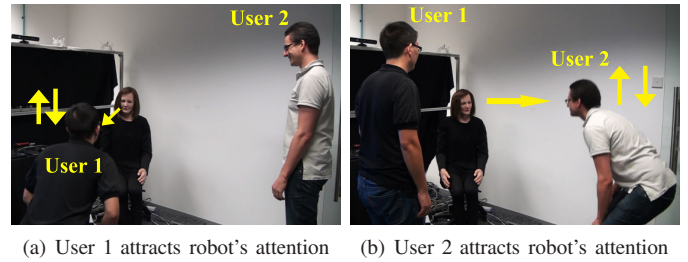


Fig. 7. Robot's attention is attracted by different users.

B. Gesture Recognition

Non-verbal language plays an important role in human-robot interaction. Therefore, understanding non-verbal language is necessary for social robots. In our research, we focus on upper-body gesture recognition. Our system allows one person to interact with a social robot using natural body language [70]. The robot understands the meaning of human upper-body gestures and expresses itself by using body movements, facial expressions and verbal language.

The gestures are characterized by the head, arm and hand posture information. The wearable Immersion CyberGlove II is used to capture the hand posture, and the Microsoft Kinect is used to capture the body skeleton. Based on the posture data from the CyberGlove II and Kinect, we built a real-time human-gesture-recognition system for the Nadine robot. Our robot can recognize at least 12 upper-body gestures, and parts of them (i.e., confidence, praising, putting up hands, drinking, reading, and writing) are shown in Figure 5.

C. Affective Computing

In order to communicate with humans naturally, social robots and virtual humans do not only need life-like appearance, but also require behaving and responding consistent with their appearance. To do so, affective computing system plays an important role. As shown in Figure 3(h), with a human realistic appearance, it is better for the Nadine robot to possess a human-like affective system.

The affective system includes five parts, i.e., detection, appraisal, processing and response [71]. This can help us to build a unique social robot with personification, believability and autonomy. Different from the previous research that only considers short-lived affection such as emotions, we focus on the long-lived affection such as the mood and personality. Our system highlights the role of mood and personality in the affective processing and response in human-robot interaction.

Inspired by the ALMA model [72], we use the personality to determine the tendency of the mood by biasing the effects of personality-consistent emotions on the mood. In addition, to take full advantage of the current mood and the personality, we propose new response algorithms in which they modulate the short-term actions and influence the long-term strategies.

Figure 6 shows a scenario that the robot makes a decision affected by its emotion state stimulated by the conversation. Figure 6(a) shows that the robot is in a blue mood since the user speaks something bad to the robot. In this situation, she feels unhappy and does not want to talk with the user any more. On the contrary, Figure 6(b) shows that she is glad to talk with the user because she and the user have a happy conversation. With the affective system, the robot will become more life-like and the human-robot interaction has been improved greatly.

D. Attention

Attention capability can make a robot more life-like. Driven by humans' daily behaviors, a novel competition selection mechanism is proposed to generate the attention focusing decision. This competition selection mechanism can control the robot's head to face to the interesting user. Our attention capture system has the advantages of multiple sensors parallel inputs and robustness. Figure 7 shows the experimental results when two real persons are talking. When User 1 is jumping and squatting, the robot's attention will be attracted by User 1 (see Figure 7(a)). Similarly, Figure 7(b) shows that User 2 attracts the robot's attention. This experiment verifies the effectiveness, robustness and flexibility of the attention capture system.

IV. CONCLUSION

This paper has provided an overview of the literature in the expanding field of social robots. It seems clear that social robots play a larger role in our daily life. They can provide services for natural communication, household services, health care, rehabilitation, and entertainment. Social robots can be used as an additional help, a tour guide, an office assistant, a medical care person, and a household staff. This paper also has shown some specific applications, i.e., multi-party interaction, gesture recognition, affective computing, and attention capture that we carry in our institute.

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