The Development of Elderly Care Robot and Current Challenges for Functional Design

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Abstract. The emergence and development of robot industry is one of the important achievements in the 20th century. After years of development, the elderly care robot can only complete some mobile auxiliary functions at the earliest, and now it can complete many functions such as detection, reminder, chat, etc. Even so, the elderly care robot is still in the direction of more functions and more wisdom. So, what is the function of elderly care robot? What should be paid attention to in the design and use of elderly care robot? Based on the needs of the elderly, this paper discusses the functions of the elderly care robot and the practical factors that the elderly care robot should consider on the premise of meeting the interests of the elderly and not violating the ethics.

1. Introduction
With the development of technology, medical technology and people's life have been greatly improved. Many countries are faced with the problem of "population aging”, in which more elderly means more medical, social and nursing services. If only the traditional way including build more nursing homes, equipment and employ more nurses were adopted, it would be hard to solve this problem. As the "aging population" will not only bring more old people but also result in the lack of young labor force due to lower of fertility rate.

For example, in 2018, the elderly aged 65 and above accounted for about 12.5% in the United States, which is expected to reach 20.7% in 2050. In terms of medical demand, according to the current growth rate, the number of Americans living in nursing homes will reach 3 million in 2030. According to the green paper of EU population, the total population of EU will reach 468.7 million by 2030, and the gap of labor population will reach 20.8 million. At that time, two labor population (i.e. population aged 15-64) will support one nonlabor population (over 65 years old)[1].

The above two data show that the core of the current problem lies in the imbalance of population structure, the increasing number of the elderly and the serious lack of young labor force, which means that not only the nursing problems of the elderly cannot be solved, but also the cost of living of the elderly can be further improved[2]. Japan is currently the most aging country in the world. It is expected that by 2060, Japan will become a society with 39.9% of the elderly population. And many welfare and care facilities are often understaffed. The number of nursing homes can not meet the number of applications for more than 524000 elderly people. Instead of building new facilities, the Japanese government began to support and encourage home-based care. Under these circumstances, the assistive technologies, which support elderly people using technologies, attract great attention[3].
With the increase of the number of elderly people, people have more urgent needs for it, so these assistive technologies are attracting more and more attention, but it is not a new thing. In the mid-1970s, France and Germany started the research and development of service robots. In 1987, the "handy" rehabilitation robot was developed in the UK. In 1990, Engelberg's "nurse assistant" robot was put into use [4]. After entering the 21st century, the application of assistive technology for the elderly has been expanding, from the former daily life of the elderly to health management, social care, and other aspects. For example, the "Pearl" robot developed by Carnegie Mellon University in the United States can remind the elderly to take medicine and monitor their health status, and the "huggable" robot can ask for hugs from the elderly [5].

To sum up, we can see that the elderly care technology has become a relatively mature field. It is true that today's elderly assistant equipment can meet the needs of the elderly through different types of auxiliary equipment, however, these are only assistant machines, not a robot. They need the elderly to use the remote control to manually manipulate or shout a word of speech using voice control. In addition, these machines are difficult to associate this sentence, observe the actual situation and combine the elderly's habits to analyze the needs of the elderly, when they can't find the remote control or the instruction given out due to memory loss lacks a certain word. Such machines only do assistant work, and can't achieve the effect of "nursing", it's true that these assistive devices can make care workers more relaxed in many places, but the elderly still need care of care workers for a long time. The difference between machinery and robot is Artificial intelligence (AI). AI technology is a key which is regarded as a structure consisting of five components namely Knowledge, the basic component and Comprehension, Perception, Communication, as well as Learning [6]. They can give robots the ability to understand and remember the old people's habits, making intelligent nursing robots possible.

2. Development of elderly care robot

2.1. Definition of robot

The word "robot" first appeared in R. U. R: Rossum's universal robots, written by Czech writer Karel Capek in 1920. After that, there were many explanations for the word "robot" [7]. According to B. Roth of Stanford University in the United States, "a robot is a kind of machine that works together with human, animal or other machines, including automatic and semi-automatic types." According to B. Espiau of CNSR: National Council of scientific research in France, robotics is a knowledge that takes the use of systems that can achieve the following goals as the research object, that is, it can complete pre-determined tasks according to the information of sensors. According to K.J. Waldron of the United States, "robot is a kind of machine with more degrees of freedom, which is used for decision-making and control by an active system with interface with mechanism" [8]. Up to now, there is no strict definition of the word "robot". As a kind of robot, there is no strict definition of service robot. The International Federation of robotics, after collecting and sorting out various data, gives a preliminary definition: "service robot is a kind of semi-autonomous or fully autonomous robot, which can complete the service work intended for human health, but does not include the equipment engaged in production". Elderly care robot is one of the service robots designed for the elderly [9].

2.2. The development of robots

At the beginning, service robots were mainly designed to meet the needs of special groups of people. In the 1970s, France's "Spartacus" operator project and Germany's "Heidelberg" project aimed at helping patients with high paraplegia opened the door of nursing robots. [4] In 1982, the Netherlands developed an experimental manipulator "RSI" which can feed and turn over books on a tea tray, providing experience and basis for the 1984 wheelchair manipulator "Manus" [10]. In 1987, a prototype of "handy1" rehabilitation robot developed by UK Mike topping helped 11-year-old boys with cerebral palsy finish eating independently. Since then, the "handy1" rehabilitation robot has been developing and innovating continuously to provide convenience for people in need [11]. In 1985, Engelberger began to develop "Rona (Robotic Nursing Assistant) " robot, which was put into production and sale in 1990 and used
in dozens of hospitals around the world. Once programmed, it can accomplish many tasks at any time[12]. The most representative robots in the United States are "Helpmate"[5]. The robots listed above are shown in Figure 1 and the specific functions of the robots listed above are shown in Table 1.

![Figure 1. Different types of elderly care robot](image)

**Table 1. Different elderly care robots**

| Robots     | Characteristics                                      |
|------------|------------------------------------------------------|
| Manus      | Simple tasks such as feeding, turn over a book, etc. |
| Handy1     | Feast, feed, wash, shave, brush, etc.                |
| Rona       | Delivery of medical equipment and equipment, meals for patients, medical records, reports and letters, medicines, test samples and test results. |
| HelpMate   | Independent walking in complex environment, such as opening door and taking elevator |

After entering the 21st century, the development direction began to expand. In 2005, Toshiba company of Japan developed a companion robot for the elderly, which realized both image and speech recognition. The elderly can control it and let the robot follow up[13]. "Paro", developed by the Japan Institute of industrial technology, is a health care robot with the function of psychological assistant therapy. It can communicate with the elderly and play an emotional role in their lives[14]. In 2015, "Pepper", developed by Softbank group of Japan and Aldebaran robotics of France, can comprehensively consider the surrounding environment and actively respond. The robot is equipped with speech recognition technology, joint technology to present beautiful posture, and emotion recognition technology to analyze expression and tone, which can communicate with human beings[15]. In 2017, inventor Stephen von rump introduced "Giraff" through video at the Health Council in minster. It enables the interaction of nursing staff, the elderly and their families in-home service and nursing service. The elderly can keep in touch with nursing staff, family and friends, and their loneliness is reduced. It has a sensor network that can detect the internal and external environment of the family, as well as the state and activity of the elderly, and feedback to the nursing staff, so as to help the nursing staff to serve the elderly better and more efficiently without rushing through the homes of the elderly[16-18]. The robots listed above are shown in Figure 2.
More recent elderly care robots

With the continuous expansion of the functions of the development of nursing robots, from action assistance, operation assistance [9] to health management, social care, etc., to communication, it can analyze the expressions and emotions of the elderly and maintain the contact between the elderly and society. Now, the development of nursing robots is still moving towards a more mature and intelligent direction without stopping.[19]

3. Elderly care robot functional design based on needs theory

The elderly care robot is designed for the elderly, that is to say, it should meet the needs of the elderly. In order to carry out the functional design of the elderly care robot, we must clarify the needs of the elderly. According to Maslow's hierarchy of needs theory (Abraham Harold Maslow, 1943)[20], human needs are divided into five levels: (1) Physiological needs; (2) Security needs; (3) Social needs; (4) Respected needs; (5) Self-realization needs. Through the above five levels of exploration, we can realize the targeted functional design of elderly care robots[21]. The above five points are shown in Figure 3.

(1) Physiological needs. Physiological needs are the lowest but the highest in the demand level, such as eating, hygiene, moving, dressing, etc. This layer is the most basic survival needs of the elderly, and the elderly care robot should first consider meeting the level of the elderly[21]. Before the 21st century, most of the basic design directions of elderly care robots were carried out at this level, for example, "Manus"[10].

(2) Security needs. Safety needs refer to the personal safety, property safety and health safety of the elderly.[22] As old people's memory would decline, it results in forgetting to close the door, window, gas, some electrical appliances, etc., which might be harmful to their lives and property. In addition, many old people will get lost, mislaid things, forget to take medicine and so on, which will cause health and safety risks. The design of the elderly robot on this floor is also a key point. It includes using sensors at home to detect gas concentration, door and window conditions, electrical conditions, etc[23], as well as reminding them to taking medicine and testing the health status of the elderly. Robots with this layer also represents a necessary design direction, such as "Jiaolong" of Shanghai Jiaotong University[24] and "Pearl" of Carnegie Mellon University in the United States[5].

(3) Social needs. This layer mainly refers to communication, emotional communication and entertainment. The elderly's physical function and mobility are reduced, while their social needs are still strong, and they are still eager to be loved and needed. Family communication, peer communication and nurse communication all contribute to the mental health of the elderly. Meanwhile, certain entertainment or music can improve the mentality of the elderly. In the design of this layer, we also need to consider that the elderly may be difficult to use the intelligent system, so the communication function is more humanized. The representative robots in this layer are "giraff"[17] with communication as the research direction and "Paro"[14] with emotional communication as the research direction.

(4) Respected needs. Everyone has the need to be recognized and respected. The respect of the elderly can never be ignored. The feeling of being respected mainly comes from two aspects: namely, the
approval from others and the feeling from the heart[21]. In the design of this layer, we should consider the unique needs of the elderly. For example, whether the elderly prefer personification[25], whether the elderly care about if robots will affect pets[26], etc., will affect the elderly's sense of respect[5].

(5) Self-fulfilling needs. This layer is the highest level, which refers to the needs that people's ideas and pursuits can achieve. After retirement for some time, the elderly usually have the needs of serving the society again, educating the third generation of families[27], etc., The elderly care robot can also try to pay attention to this part, and become a medium for the elderly to convey the outside world and introduce themselves. To accomplish anything meaningful will greatly meet the needs of self-realization of the elderly.

- Serving the society again
- Educating the third generation
- Approval from others
- Feeling from the heart
- Communication
- Emotional communication
- Entertainment
- Personal safety
- Property safety
- Health safety
- Eating
- Hygiene
- Moving
- Dressing

Figure 3. The needs theory for elderly care robot functional design

4. Practical problems to be considered in the design process

In order to meet the needs of the elderly, the elderly care robot itself must have many functions, some functions will indeed have many benefits, but in the process of design or use, there will inevitably be some practical problems.

4.1. Cost
This refers to the manufacturing cost of the elderly care robot itself and the purchase cost of consumers. Because each elderly has their own preferences, the robot needs personalized design[28], which will inevitably increase the cost of the robot. In addition, we should consider the economic situation of the elderly in different regions[2]. At present, due to the high cost, it is still difficult for the elderly care robot to enter the ordinary family[4].

4.2. Ethical issues
In the process of using robots, how to protect the benefits of the elderly and do not violate the ethical values of research is a very important part, that is, the physical and psychological welfare of the elderly is as important as the welfare of other people[29]. Specifically, this could be explained in the following different aspects, in detail.

4.2.1. The amount of social contact of the elderly is reduced. To some extent, the elderly care robot is to make the elderly stay at home longer and more safely, which will inevitably affect the amount of
social activities of the elderly at home[3]. Research shows that the elderly with high social participation have higher quality of life and lower level of physiological and cognitive disorders[30].

4.2.2. Rights and interests of the elderly. How many functions should elderly care robots open to the elderly? Can offspring or nursing workers use more functions or restrict the elderly to use some functions? Although some functions may need to be banned in some cases, this will still affect the rights and interests of the elderly to a certain extent.

4.2.3. Violation of privacy. In the process of nursing, the elderly care robot will inevitably encounter some privacy problems on working. For instance, when the bathing robot helps the elderly to bathe or the changing robot changes clothes for the elderly, it will involve body privacy. Besides, some robots can detect the security of the house, their detectors often detect and store the situation in the house of the elderly, which involves property privacy. To some extent, this weakens the initiative of the elderly[29]. Research shows that more than 72% of the elderly are willing to accept home-based monitoring, and 60% of them are concerned about privacy and security issues in the monitoring process[31], which shows that the elderly pay attention to privacy.

4.2.4. Responsibility attribution, human rights, and morality are inextricably linked, but more from the perspective of legislation, rather than practical ethics[29]. Due to different national policies and laws and regulations, the division of responsibility is different. At present, there is not a sound responsibility system for the elderly care robot in many countries[4]. For example, if the elderly refuse to take medicine assisted by the nursing robot, who is responsible for the consequences, the manufacturer or the elderly themselves? Additionally, if the old people pour too much emotion into the nursing robot, and the new psychological diseases of the old people are caused by it[32], how to divide the cost of treatment? If these problems are only viewed from the perspective of morality and human values, there will be totally different views from different perspectives. If there is no sound legal system to divide them, it is difficult to determine the responsibility.

5. Conclusion
This paper discussed the functional design of the elderly care robot and the practical factors to be considered in the design. The research on elderly care robot has been developing for many years. Currently, the elderly care robot can accomplish many tasks. Whether it is reminder, detection, call or mobile assistance, it can almost meet most of the needs of the elderly. However, with more and more functions, the scope of functions is more and more wide, and many problems also follow, including the lack of practicability of some functions, privacy issues of the elderly, etc.

Some impractical and unnecessary functions not only make the system more complex, but also increase the cost. Hence, it is necessary to establish a theory to carry out the function design of the elderly care robot. The function design based on the needs of the elderly is reviewed considering that the elderly care robot is emerging for the elderly care. The needs theory determines many practical and necessary functions, at the same time. Specifically, the design of these functions should consider the feelings, privacy, and rights of the elderly.

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References
[1] CINR. http://www.chinairn.com/scfx/20181112/113414456.shtml (accessed.
[2] Reinhardt U E, "Does the aging of the population really drive the demand for health care?," Health Aff (Millwood), vol. 22, no. 6, pp. 27-39, Nov-Dec 2003, doi: 10.1377/hlthaff.22.6.27.
Tokunaga S, Horiuchi H, Tamamizu K, Saiki S, Nakamura M, and Yasuda K, "Deploying service integration agent for personalized smart elderly care," 2016.

Maoni Z and Qianfan L, "Enlightment from development of foreign care robots for the age," School of Nursing, New Campus of Zhengzhou University, Zhengzhou 450000, China, no. 3.

Ke L, Junqing X, and Guilan K, "Functional requirements of elderly health care robots," China Information Industry, no. 03, pp. 90-93, 2018.

Davydov O I. and Platonov A K, "Robot and Artificial Intelligence. Technocratic approach," p. 112, 2017.

Wowen W, "The development of robot in the world," Defense Technology, no. 1, pp. 70-75, 2001.

McGraw H 1986, "Standard Handbook of Machine Design[M]."

Lanlan Y, "Ergonomical Design and Application of Free-old Robotic Bed," School of Mechanical Engineering Automation Beihang University, Beijing, China, 2011.

Rosier J C, Woerden J. A. Van, Kolk L. W. Van Der, Driessen B. J. F and Bruyn P. M, "Rehabilitation robotics: the MANUS concept," in Advanced Robotics, 1991. 'Robots in Unstructured Environments', 91 ICAR., Fifth International Conference on, 1991.

Tingting Z and Jing C, "The application of the elderly care service robot in China," Management Observation, no. 10, pp. 139-141.

I. t. s. robot. http://ishare.iask.sina.com.cn/f/34hOfoUhzsh.html (accessed.

Koga T, Suzuki K, Hirokawa J, Ogawa H and Matsuhiro N, "ApriAlpha V3 - sharp ear robot - and the omni-directional auditory process," 2007.

Sabanovic S, Bennett C C, Chang W L and Huber L, "PARO robot affects diverse interaction modalities in group sensory therapy for older adults with dementia," IEEE International Conference on Rehabilitation Robotics: [proceedings]. vol. 2013, pp. 1-6, 2013.

Amit P and Gelin R, "A Mass-Produced Sociable Humanoid Robot: Pepper: The First Machine of Its Kind," IEEE Robotics & Automation Magazine. pp. 1-1.

Portugal D, Trindade P, Christodoulou E, Samaras G and Dias J, "On the development of a service robot for social interaction with the elderly," 2016.

Coradeschi S, Cesta A, Cortellessa G, Coraci L and Östlund B, GiraffPlus: A System for Monitoring Activities and Physiological Parameters and Promoting Social Interaction for Elderly. 2014.

T. h. o. E. r. i. S. r. Valley. http://www.sohu.com/a/250668324_693803 (accessed.

Dounas C, Metsis V, Becker Eric, Le Zhengyi and Maglogiannis I, "Digital cities of the future: Extending @home assistive technologies for the elderly and the disabled," Telematics & Informatics, vol. 28, no. 3, pp. 176-190, 2011.

Anderson A, "Maslow's Hierarchy of Needs," vol. 67, no. 2, pp. 172–178, 2014.

Yue S, "Research on the elderly nursing robot design based on design affairology," Yanshan University.

Sinoff G and Perla W, "Anxiety disorder and accompanying subjective memory loss in the elderly as a predictor of future cognitive decline," International Journal of Geriatric Psychiatry, vol. 18, no. 10, pp. 951-959.

Chifor B C, Bica I, Patriciu V. V and Pop F, "A security authorization scheme for smart home Internet of Things devices," Future Generation Computer Systems, p. S0167739X17311020.

Bo Wen L, "Jiaolong service robot project," Knowledge of modern physics, no. 3, p. 2.

Duffy B R, "Anthropomorphism and the social robot," Robotics & Autonomous Systems, vol. 42, no. 3-4, pp. 177-190.

Scopelliti M, "If I had a robot at home... peoples' representation of domestic robots," Designing A More Inclusive World, 2006.

Ya L, Yun Li Y, Chao Y, Hong J, Jun Xiang L, Jun Hui Z and Dong Fu C, "A study on the mental health status and influencing factors of the elderly," Journal of Community Medicine. no. 13, pp. 61-62.
[28] Ho Seok A, IHan K, Chandan D, Rebecca S, Ngaire K, Kathy P, Elizabeth B and Bruce A M, "Design of a Kiosk Type Healthcare Robot System for Older People in Private and Public Places," 2014.

[29] Sharkey A and Sharkey N, *Granny and the robots: ethical issues in robot care for the elderly*. 2012, pp. 27-40.

[30] Thomas P A, "Trajectories of Social Engagement and Mortality in Late Life," vol. 52, no. 4, pp. 430-443, 2011.

[31] Boise L, Wild K, Mattek N, Ruhl M, Dodge H H and Kaye J, "Willingness of older adults to share data and privacy concerns after exposure to unobtrusive in-home monitoring," *Gerontechnology*, vol. 11, no. 3.

[32] Frennert S and ?stlund B, "Review: Seven Matters of Concern of Social Robots and Older People," *International Journal of Social Robotics*, vol. 6, no. 2, pp. 299-310.