The Rise and Development of Intelligent Assistive Devices and Rehabilitation Robot in China

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Abstract- The concept and classification of the intelligent assistive devices and rehabilitation robot are introduced in this paper; Domestic intelligence assistive devices include intelligent prosthetics, intelligent orthotics, intelligent walker, assistive devices for smart home environment control and intelligent life assistive devices; Domestic rehabilitation robot includes upper limb rehabilitation robot, hand rehabilitation robot, lower limb rehabilitation robot, robotic smart wheelchair, intelligent nursing bed and daily care robot. The developmental trend of intelligent assistive devices and rehabilitation robot are also introduced.

Keywords- China; Intelligent Assistive Devices; Rehabilitation Robot

I. INTRODUCTION

Assistive devices, is one of the most direct and effective ways to help disabled people compensate and improve function and quality of life and enhance the participation of social life of ability [1].

II. THE CONCEPT AND CLASSIFICATION OF THE INTELLIGENT ASSISTIVE DEVICES

Artificial intelligence was used as the basic technology method into the intelligence assistive devices, assembling a model in the executive system of the assistive device which was directing the movement of all the organs of human body like the brain does, thus equip this device the ability of "perceiving the changing of external environment", "analyzing and judging the current situation", "controlling all the body organs", and "providing feedback of the operation results". This assistive device has very quick perception and can make proper adjustments for varies requirements of different assignments as it highly simulated the human's ability of collecting information of sensory organs, analyzing and concluding information of brain, and movement of body directed by the brain.

The concept of the intelligent assistive devices is novel [2]. "The research and development of intelligent living assistive devices for disabled people" was included in the Top Ten scientific and technological achievements in the field of social development in the 11th Five-Year by Social Development Division of the Ministry of Science and Technology in February, 2011.

Intelligent assistive devices include intelligent prosthetics, intelligent wheelchair, intelligent orthotics, intelligent mobile assistive devices, smart home environment control assistive devices, the smart living assistive devices, intelligent rehabilitation robot and so on. During the time of the 11th Five-Year, the science and technology department and industry department are actively promoting the research and development of the intelligent assistive devices, Ministry of Science supported major research projects specifically for severe disabilities through Technology Support Program, 863 Program of the National Science and Technology Plan, some of them got a number of high-level scientific achievements, including some new iconic intelligent living assistive devices, which laid a solid foundation for further study, as well as promoted intelligent assistive device in China.

III. DOMESTIC INTELLIGENT ASSISTIVE DEVICES

A. Intelligent Prosthetics (i Prosthetics)

Intelligent prosthetics is an integration system made up of man, computer and control system, and also an important development direction of the of rehabilitation assistive devices. Intelligent prostheses differ from traditional prosthetic possess by perception of external conditions change and adaptive capacity, and bringing more comfort.

Smart knee studies in China began in 1994. Biological-mechanical and electrical integration prosthetic prototype was invented in Shanghai Jiao Tong University, the CIP-I intelligent artificial leg, which was invented in Central South University, would naturally follow the pace of the wearer. Hebei University of Technology, National Research Center for Rehabilitation Technical Aids, Tsinghua University successfully jointly developed a domestic smart prosthetics Pressure knee. The knee with a four-link and pneumatic cylinder integrated design use senor to get gait and pace recognition. Intelligent controller can be automatically adjusted cylinder valve opening according to the wearer's walking speed, real-time adjust swing speed of prosthetics (Figure 1).

Figure 1 Domestic smart prosthetics pressure of knee joint

In 2012, air pressure damping adjustable intelligent prosthetic foot was developed, bionic ankle foot integration comes true. The bionic thigh prosthetics coordination controllers simultaneously controlling the movement of the prosthetic knee and ankle foot and integration of ankle-foot devices have been developed, performance testing and clinical trial validation have been done for the devices (Figure 2).

Figure 2 Bionic AK prosthetics

The research of the intelligent knee (Figure3) has been undertaken by Institute of Biomechanics and Rehabilitation Engineering of the University of Shanghai for Science and Technology in recent years, intelligent control following gait based on CMAC neural network.

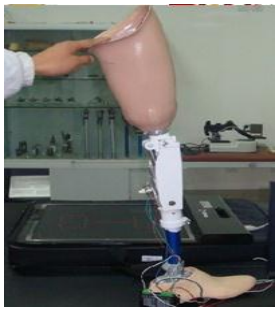

Figure 3 Intelligent knee

B. Intelligent Orthotics (i Orthotics)

Intelligent orthotics in the international arena is also a brand new conception, the present study mainly includes the upper limb intelligent orthotics and lower extremity smart orthotics.

From a functional point of view, the exoskeleton robot (powered exoskeleton) belonging to the category of orthotics is the wearable robots which can close fit the limb of a wearer and move together, and also can satisfy the human mobility and support needs through the provision of external force. Exoskeleton rehabilitation robots are gradually replacing the early terminal guiding rehabilitation robot.

In recent years, a wearable assisted exoskeleton was developed by Y.J. Ge, a researcher of Hefei Institute of Intelligent Machines of the Chinese Academy of Sciences, important results were achieved in the sensor signal acquisition recognition of human gesture. The lower limbs power bones based on the hydraulic control were developed by Professor Cao Heng in East China University of Science and Technology, he explored limbs supple problem under heavy load conditions. Much research work about power exoskeleton intelligent orthotics was done by Shanghai Jiao Tong University, Harbin Engineering University and other research institutes.

1) Upper Limb Exoskeleton Robot:

During 1990s the study of human-machine integration theory has began in State Key Laboratory of Fluid Power Transmission and Control in Zhejiang University, and gradually the technology of human-computer intelligent flexible exoskeleton has been derived, the upper extremity flexible exoskeleton control system which is actually an intelligent upper extremity orthotics has been developed [3]. Tsinghua University and the People's Liberation Army General Hospital jointly developed upper limb rehabilitation robot, after ten years of development, the fourth generation of robot training plane can flip to expand the training ranges from two-dimensional to three-dimensional, adding dual-screen visual feedback, training effect is more obvious, there are three kinds of training mode which applies electrical stimulation to the rehabilitation process, joining the vibration feedback sensing system with the cooperation of Stanford University, achieving a certain effect. An "exoskeleton upper limb rehabilitation robot experimental prototype" has been developed in Institute of Biomechanics and Rehabilitation Engineering of the University of Shanghai for Science and Technology. In 2012, the virtual training system for rehabilitation of the patients with upper limb amputation and the exoskeleton training system (Figure 4) for upper limb rehabilitation of the patients with hemiplegia were developed by National Research Center for Rehabilitation Technical Aids.

Figure 4 The exoskeleton training system

2) Lower Limb Exoskeleton Robot:

The wearable lower extremity exoskeleton walking robot in Zhejiang University mainly helps stroke patients do rehabilitation in the room, preventing patients with muscle disuse atrophy, partial recovery the walking function of patients. Without power exoskeletal rehabilitation robot which was developed in Shanghai Jiao Tong University has gravity compensation function, this robot is available for the incomplete paralysis or paresis whose muscle strength from two to five doing active movement training; Lower limb rehabilitation walker institutions were designed and developed in Harbin Institute of Technology, including uplift institutions of a walker walking institutions worn on the body. Through these two devices, patients can do functional exercises to restore health in the case of without the help of others. Recently a lower extremity gait orthotics is developed by Shanghai University.

Some related research institutions, for example Tsinghua University(Figure 5), Shanghai Jiao Tong University, Xi'an Jiao Tong University, Tianjin University, Hebei University of Technology, Hefei Intelligent Machinery Institute of the Chinese Academy of Sciences, is doing research about the lower extremity exoskeleton technology, and also got some useful exploration in the field [4].

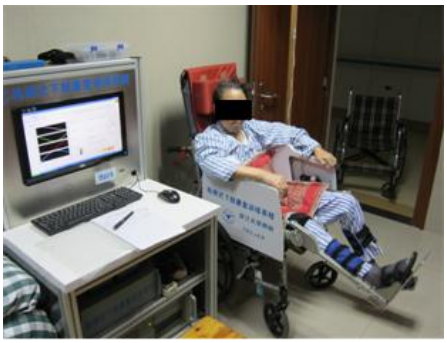

Figure 5 Lower extremity exoskeleton by Tsinghua University

C. Intelligent Walker (I Walker):

In order to help and improve the walking capacity of the people with lower extremity functional disorder, intelligent walker has become a domestic and international hot research field of robotics and rehabilitation [5]. Supine lower extremity walker robot, multifunction walker robots have been successfully invented. The walking training system for paraplegics jointly developed by Tsinghua University, the National Research Center for Rehabilitation Technical Aids, break many key

technologies, for example the joint reverse drive and waist with a mechanism, trajectory planning and hip and knee coordinated control and so on. According to the patient height automatically generated gait trajectory intelligent multi-joint coordinated motion control system was designed, to help paraplegia and other lower extremity motor dysfunction in patients do ambulation training, restoring their walking function. The full range of mobile walking aid robot with the man-machine coordinate security master-slave control technology developed by Nankai University has a full range of zero turning radius, and can identify the intent of the person, helping to walk (Figure 6.).

Figure 6 Mobile walking aid robot

D. Smart Home Environment Control Assistive Devices

Intelligent environmental control assistive devices help severe disabilities to control household electrical equipment in the home, which can be used to open the door, open the curtains, dial the phone, and turn on the light and TV. The key of the system is providing a human-machine interface between the function of the disabled people and the electrical equipment. The function used is often a certain part of the operation, such as fretting of a finger, eye movements, voice, blowing, and so on. The man-machine interface is made up of the sensor, the processing circuit and the signal transmitting, through which the human motion is translated into the electrical signal and coupled with the required operating equipment [6]. The study of the environmental control system based on the brain - machine interface is attracting national attention [7].

Our smart home as the application of Things in real life is more and more widespread concerned in society. Accessibility voice control system of home environment for severely handicapped was successfully developed in 2010. Smart home terminal, the instrument of smart bedroom eyes manipulation, the elderly smart home technology integration platform is prepared.

E. Intelligent Living Assistive Devices:

Intelligent living assistive devices are short for assistive devices for personal care and protection. It is the assistive device, due to some handicapped dysfunction can not complete one or more activities of daily living, improving the ability of the patients to reduce the inconvenience brought about by the dysfunction, so that the patient can complete some of the activities of daily living which cannot be completed before in a more effective, time-saving and high-quality manner, and increase the independence of living. Intelligent life at home and abroad assistive devices divided into several categories, including smart diet assistive devices, smart nursing assistive devices for toilet, intelligent nursing bed, intelligent environmental control system and the daily care robots, etc. Quite a lot of smart living assistive devices products have been commercialized and directly used for institutions or family.

1) Smart Diet Assistive Devices:

Recently the domestic intelligent life assistive devices robot named “Kejia” developed by China University of Technology, use a microwave to do popcorn.

2) The Severe Disabilities Smart Bath Assistive Devices:

The severe disabilities smart bath assistive devices jointly developed by National Research Center for Rehabilitation Technical Aids, Tianjin University of Science and Technology, Huazhong University of Science and Technology is the first time, systematically solve the problem of the severely handicapped auxiliary bath, improving the quality of life of the severe disabilities. The project includes designing the structure of the bath devices based on the ergonomic, the technology of the intelligent control detection unit, web-based emergency call and alarm technology. Two auxiliary bath devices for severely disabled were developed, the one is a slide auxiliary bath device; the other is an auxiliary bathing device with lift platform. Severely disabled can control the water temperature by voice, the system can recognize more than 10 kinds voice commands, with preventing rollover function, alarm function for drowning and falling risk. The device firstly systematically solves the assisted bathing problems for the severely disabled people in our country and improves the quality of life of severely handicapped persons (Figure 7).

Figure 7 Smart bath assistive device

IV. DOMESTIC REHABILITATION ROBOT

The rehabilitation robot is a new type of robot. It belongs to the scope of medical robots. It is divided into rehabilitation robot and assisted rehabilitation robot. The rehabilitation robot's main function is to help patients complete the recovery of motor function training, such as walking training, arm training, spine training, neck training and so on. Through doing thousands of repetitive motion to drive limb training, rehabilitation robot can stimulate and rebuild the nerve of the controlled limb movement, thereby restores limb motor function, this way is a new clinical intervention way.

Jiangsu university (mechanical engineering institute) combined with Jimei university (mechanical engineering institute) developed a new type of traditional Chinese medicine department of traumatology medical massage robot. A robot which can give a person massage and bathing has been successfully developed by Mercury-person Company. This massage robot has realized three technological breakthroughs about automatic looking for positioning the human body acupuncture point, machine active massage, machine massage from up to down.

A. Upper Limb Rehabilitation Robot

The research of a force feedback teleportation robotics and web-based remote upper limb rehabilitation robot have been launched since 1992 by Sciences Institute of Intelligent Machines of the Chinese Academy, Shenyang Institute of Automation, Southeast University of Chinese Academy of Sciences, Beijing University of Aeronautics and Astronautics, Tsinghua University, Harbin University and other colleges and universities. Since 2001, the Harbin Institute of Technology, Tsinghua University, Southeast University, Harbin Engineering University, have conducted research for remote operation of the rehabilitation robotics. Southeast University in cooperation with Northwestern University Intelligent Mechanical Systems Laboratory successfully developed a practical remote upper limb rehabilitation system, and also successfully developed the human neuromuscular electrical signal intelligent detector and EEG detector. In recent years, Many rehabilitation robots have been successfully developed, for example composite motion of shoulder and elbow rehabilitation robot, shoulder rehabilitation robot and hand rehabilitation robot and others, and clinical application were done, got a large number of clinical data, and preliminary results have been observed in the rehabilitation of the old hemiplegic patients; two-bar linkage rehabilitation device, 5 DOF upper limb rehabilitation robot, upper extremity hemiplegia rehabilitation robot and motor function rehabilitation robot have been developed.

B. Hand Rehabilitation Robot

Domestic research institutions developed some of the non-market-oriented training devices, such as the hand function rehabilitation bionic gloves using stimulating electrodes for functional electrical stimulation on the muscles. The technology of wearable multi-degree-of-freedom hand function rehabilitation robotics mainly contains the development of hand rehabilitation robot prototype, cooperative control of the patients with active intent, virtual reality technology and so on. These research institutions carried out research for the technology of the rehabilitation robotics remote operation, successful researched the practical remote upper limb rehabilitation system, EMG signal intelligent detector and EEG intelligent detector.

C. Lower Limb Rehabilitation Robot

Lower limb rehabilitation robotics is the international forefront of technology. Our research institutions have made great breakthroughs in many aspects such as the new mechanism design, control strategy, supple drive and control, human-computer interaction, virtual reality, biofeedback adaptive and so on. Research results have recumbent position lower limb rehabilitation robot, multi-function walker robots. The multi-functional lower extremity rehabilitation robot jointly developed by Harbin Engineering University, Tsinghua University, Industrial Technology Research Institute in Kunshan can simulate walking trajectories of normal people to train patients [8].

The paraplegia rehabilitation robot (Figure 8) jointly developed by Chang'an University, Shaanxi Gospel Zhongda Electronic Science and Technology Co., Ltd., is mainly used for the rehabilitation of paraplegics and walking. It enables patients to stand up and walk like a normal person, is a wearable rehabilitation robot which is made up of motion control module, sensor module, the servo drive system and a mechanical linkage, low-voltage DC power supply, etc. as shown in Figure 1. The thigh and calf, respectively, with four servo motor drive, under the action of control module, the patients can do many actions for example stand up and sit down, walking single-step, continuous walking, standing still, and the downstairs.

The robot is gait natural, safe and reliable, with automatic and manual free switching function. This robot is suitable for paraplegics in T4 and T4 following completely or incomplete spinal cord injury as well as all lower extremity muscle weakness.

Figure 8 Paraplegics rehabilitation robot

The Professor Ji Linhong of the Tsinghua University developed the lower limb rehabilitation robot (Figure 9) with more than posture based on the upright bed in 2011, and, providing early hemiplegic patients rehabilitation of gait simulation of the lower extremity muscles and joints. He proposed a lower limb rehabilitation training method, efficiently stimulating the central nervous system with non-rhythmic movement, developed the hanging lower extremity exercise and walking ability training system of the exoskeleton rehabilitation robot and the exoskeleton rehabilitation robot system based on the standing bed and wheelchair, the system provides equipment and training methods for the hemiplegia patients who need the early rehabilitation of multi-joint coordination movement and comprehensive ability, to prevent early complications, and fills the domestic blank in this field.

Figure 9 Lower limb rehabilitation robot

Since "Flexbot multi postural intelligent lower limb rehabilitation robot system" running more than one year in the rehabilitation Medical Center of the Jiaxing Second Hospital in Zhejiang Province, more than 50 stroke patients achieve early rehabilitation training.

D. Intelligent Wheelchair

The smart wheelchair is the electric wheelchair applying intelligent robot technology, the integration of a variety of areas, including machine vision, robot navigation and positioning, pattern recognition, multi-sensor fusion, and user interface. The intelligent wheelchair is also known as intelligent wheelchair mobile robot or wheelchair-based rehabilitation robot [9].

The automatic navigation intelligent wheelchair developed by Chinese Academy of Sciences is the smart wheelchair with a visual and password navigation features and voice to interact with people. It is the country's first multi-modal interactive intelligent wheelchair prototype. The basic functions of the system of intelligent indoor electric wheelchairs helping move developed in 2012 is: you can change the attitude to meet the need of the user for lying, sitting and standing; you can take advantage of the visual servo technology independent traffic bedstead; up and down the stairs. Shanghai Jiao Tong University has developed a voice-activated wheelchair which was designed for people who lose their limb functions. The users can simply give some commands like "open", "advance", "back", "left", "right", "fast", "slow" and "stop". The wheelchair can identify the meaning of the instructions and complete the instructions given in the action within 1.2 s. China's "Eleventh Five-Year Plan" key support for the service robot project – Help Age assistive robot system, intelligent wheelchair with the function of

differential drive control, smooth starts and stops, stable running, real-time obstacle avoidance Parking in “863 plan” has been developed. The seats of high-level wheelchair can freely lift, backrest can freely tilt. The bed and wheelchair achieved butt joint, convenient for staff on the bed by themselves; automatically avoid obstacles moving, automatic alarm for falling and tipping, but also can detect the user’s health status in real-time.

E. Smart Care Bed

Currently the domestic intelligent multifunction care bed is more similar to the robot. The user of the intelligent multi-function nursing bed can easily control intelligent multifunction care bed movement by voice, remote control, touch screen, achieve many functions such as auxiliary lift back to sit up, flexion and extension of the legs, turning around, lying down, auxiliary going to the toilet, detection of human physiological parameters, call alarm and so on. Domestic dedicated living bed for disabled has broken some key technologies, for example intelligent control, human-computer interaction, physiological information detection, anti-bedsores and others. Three kind’s beds with different functions and different grades have been developed. The product design is modular, plug-and-play. According to the division of the functional modules, nursing bed has five functions, each function can accord need to increase or decrease. Intelligent nursing bed with anti-dropping features and multi-functional new smart care bed were developed by the University of Shanghai for Science and Technology in 2011. E-Bed (Figure 10) was developed by Beijing University of Aeronautics and Astronautics in 2012, achieving bed - chair integration.

Figure 10 E-Bed

F. Daily Care Robot

The first domestic care robot was unveiled in Nanjing. A health care robot met with the audience in " The 14th International High-Tech Expo " held in Beijing in May 18, 2011. The robot can communicate with the sick elders, play video and provide consultation and simple care.

A severe disability care robot (Figure 11) with bottled water, feeding, nursing function was developed by Harbin Engineering University.

Figure 11 Severe disability care

The service robot for the elderly was developed by the Chinese Academy of Sciences hospital in Hefei Institutes of Physical Science in April, 2012. The life-size robot achieves many functions such as autonomous mobile, pick-up and delivery of commonly used items, speech recognition and simple dialogue, smart entertainment, fall detection and remote alarm function. If the elder at home fell, the robot will issue a requesting assistance message, to ensure that at the first time notify relatives of the elder. If they are thirsty, as long as issuing voice commands, it will immediately handed cups of water. It will also remind the elder to take medicine, accompany the elder chat, play chess, tai chi. The elder can watch part of the entertainment through chest viewing screen, achieving psychological counseling.

V. DEVELOPMENT TREND OF INTELLIGENT ASSISTIVE DEVICES AND REHABILITATION ROBOT

A. Intelligent Assistive Devices And Rehabilitation Robots Become the Focus of Competition in the Field of Global Industry

Intelligent assistive device industry in China is facing daunting challenges: enterprises operating scale in China is small size, industry competition overall lacks of strength, industrial base is weak, industry chain is incomplete, industrial scale, brand and overall competitiveness is weak, the research of development of the production is relatively low, there is a certain gap in

the aspect of overall performance and reliability. Part of the high-end smart assistive devices also cannot grasp the core technology and key components, it is difficult to compete with foreign enterprises, it is at a disadvantage in the competition of the industry.

B. Strategic Research Planning of Intelligent Assistive Devices and Rehabilitation Robot

Ministry of Science and Medical Device Technology industry "Twelve Five" special plan proposed: Given the requirement that "everyone has the right to receive rehabilitation treatment", and the trend that Generalized System of Preferences, intelligence and individuation are inevitable, we should devote ourselves to researching technologies which are based on structure alternatives, functional compensation, skills training and environmental transformation, we should also dedicate ourselves to developing intelligent assistive devices such as myoelectric and neuro-control prostheses and Cochlear implant, developing functional training systems for the elderly people and rehabilitation training systems for stroke patients and disabled person. It will undoubtedly contribute to the research on the intelligent and low-cost rehabilitation technical assistive devices and will promote the popularity of the rehabilitation technical assistive devices.

With the development of robotics, artificial intelligence robot which is not only miniaturization and lightweight, but also closer to practical is continually developed. People are looking forward to the future of intelligent assistive devices and rehabilitation robot.

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