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Design of Rehabilitation Robot with Combined Movement of Arms and Legs

ZHANG Ying[a] (张　莹), *FANG Juan*[b] (方　娟), *XIE Le*[a,b*] (谢　叻)
(a. National Engineering Research Center of Die & Mold CAD;
b. Institute of Rehabilitation Engineering, Shanghai Jiaotong University, Shanghai 200030, China)

Abstract: Rehabilitation instruments are effective tools for patients to recover from disability. However, we still do not have a rehabilitation instrument which could provide combined movement with arms and legs. Rehabilitation with combined movement of arms and legs is completely a new method. In order to check the effect of this new rehabilitation method and to provide patients with more efficient rehabilitation instrument, we design a new rehabilitation robot. This robot lets patients practice when they lie down and stand up. This article explains the design of this instrument clearly. Using Unigraphics NX software to build 3D model, we have a complete design of this rehabilitation robot.
Key words: combined movement, arms and legs, rehabilitation exercise, rehabilitation robot
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0 Introduction

There are many rehabilitation robots on the market. However, there is still no functional rehabilitation robot which could provide combined movement of arms and legs for patients. According to the study of many scientists, there are connections between the movement of arms and the movement of legs, which infers that rehabilitation with combined movement of arms and legs will be a possible effective way for recovery process of disabled limbs. In order to test the effectiveness of this method, we designed a rehabilitation robot which could provide combined movement of arms and legs for patients by using 3D model software and simulation software. This paper introduces the advanced concept and the main structures of this robot.

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∗**E-mail:** lexie@sjtu.edu.cn

1 Research Situation of Rehabilitation Robot

Many diseases will lead to a sequela of losing movement ability. Stroke and spinal cord injury are two main kinds of diseases leading to losing movement ability. Promoting technology-based integrated sports therapy can suppress abnormal movement patterns and induce normal movement patterns of Stroke patients[1]. Patients of spinal cord injury need functional rehabilitation exercise which keeps paralyzed muscles and joints active through initiative training or passive training.

1.1 Overseas Research Situation

The research of lower limb rehabilitation robot begins early. The exoskeleton robot Lokomat invited by Switzerland scientist Jerry Colombo is the first device focusing on rehabilitating patients who has spinal cord injuries, cerebral apoplexy and other nerves impairment[2-3]. The Freie University Berlin of Germany invited a rehabilitation robot called MGT in 1996, which consists of weight support system, moveable part and driving system. This robot could provide gravity compensation for different patients and control their center of gravity[4-5]. Then the Freie University Berlin of Germany added computer control system on the MGT to form a new rehabilitation robot Haptic Walker, which can assist in rehabilitating with different trajectories[6]. With the development of technology, people begin to study intelligent rehabilitation robots. By detecting electromyographic signals the

hybrid assistive leg (HAL) invited by Tsukuba University in Japan can controls the movement of body with an artificial intelligence system[7-8].

1.2 Domestic Research Situation

Research of rehabilitation robots in China begins late and is fragmented. The research in Harbin Engineering University about lower limb rehabilitation robot is relatively comprehensive, which includes hardware design, basic theories and initial instruments[9]. In 2004 University of Science and Technology of China did deep research about control and dynamics modeling of lower limb exoskeleton robot, which provided basic theories for further research[10]. Recently, the Institute of Rehabilitation Engineering in Shanghai Jiao Tong University has invited a robot which can assist patients to stand and help patients to practice walking[11].

1.3 Summary

Although much research has been done about rehabilitation robots no matter in domestic area or overseas, there is still no research about rehabilitation robot which can provide combined movement with arms and legs so far. However, there was enough medical research about the connections between the movement of arms and legs. What we want to implore is the possibility of rehabilitating with combined movement of arms and legs.

2 Theoretical Basis of the Rehabilitation Robot

In nature, all quadrupeds walk using both front and hind legs. Although humans are senior animals and can walk upright, their walking is still a combined movement of arms and legs. When humans are walking, their arms swing naturally keeping balance of their bodies. In 1985 Finch put a cat whose spinal had been cut off on anelectric treadmill letting it walk again and again. After a while of the walking training the cat gained walking ability again[12]. Then the research of American scientists Helen Huang and Daniel Ferris showed that movement of arms and legs react and affect each other through nerves[13]. Other scientists found that movement of arms can output electronic signals which are essential for the recovery of legs[14].

All of these studies show that there is possibility to improve recovery procedure by connecting the movement of arms and legs.

3 Structure Design

3.1 Multi-Gesture Function

Normally, the height of the robot is 500—600 mm which lets patients move on to this robot from their wheelchairs easily. After training for a while, in order to fasten the progress the robot can help patients do rehabilitation exercise with standing gesture.

The elevator mechanism is putted on two sides of the robot in order to leave enough space for patients to move their legs when they are standing (Fig. 1). The elevator mechanism controlled by motors contains two cross links moving to different sides. The links of elevator mechanism which touch ground can prevent the robot from falling when the gesture is changing (Fig. 2).

Fig. 1 Elevator mechanism

Fig. 2 Standing gesture

3.2 Structure Adaptability

For different person has different physical characteristics the arm part and the leg part can be adjusted according to patients' body sizes. We can see the arm part in Fig. 3. There is a revolute joint which equals to elbow joint. The adjust mechanism is designed to be able to be adjusted quickly because it does not need to bear too much heavy and convenience is more important.

The leg part (Fig. 4) uses screw coupling mechanism which is not convenient to adjust but can bear heaver load. This coupling method can assure the reliability of the design. Between thigh part and shank part there is also a revolute joint which equals to knee joint.

Fig. 3 Arm part

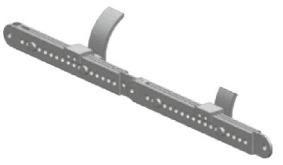

Fig. 4 Leg part

3.3 Movement Function

The most significant role of this rehabilitation robot is that it can provide combined movement with arms and legs. Considering movement characteristics of humans, we let the working sheet provide comfortable practice environment for patients (Fig. 5).

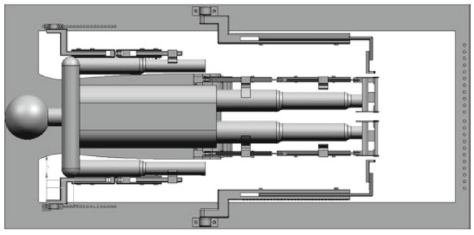

Fig. 5 Design of working sheet to keep enough moving space for arms and legs

Firstly, cut down the places which impede the movement of arms and legs. Secondly, the arm part cannot be settled in one place for the body size of different patient is different. The width between two leg parts can be adjusted too. Lastly, there is supporting sheet on foot part which can not only take leg to move but also keep patients' legs from falling down.

The movement of arm part is driven by motor which is settled in the place of shoulder joint. The leg part contains inner one and out one. The inner leg is connected with patient' leg. The out leg driven by motor is the driven unit which is combined with inner leg through foot part. This design can leave enough space for moving arms.

3.4 Foot Trajectory

According to materials, we know that ankle trajectory, heel trajectory and toe trajectory could be well modeled by a rigid pendulum. The pendulum modeliship-centered with pendulum length approximately equals to the segment distances from the hip. This movement model is achieved by guide rails, motors and foot parts. The guide rail restricts foot part to certain trajectory. The foot part is connected with guide rail and driven by out leg to form pendulum movement.

4 Conclusion

This article introduces the concept of rehabilitation robot with combined movement of arms and legs and the way to fulfill this concept. This rehabilitation method is completely a new rehabilitation method and there is no rehabilitation instrument using this method for now. Using UG software to build 3D model and simulation software to check movement interference, we keep improving our design. It is always the most priority principle that let patients rehabilitate with the new method and practice in comfortable and convenient environment. The design of this rehabilitation robot meets the requiretments such as comfortable, practical, adaptable and safe in ergonomics, also fulfills the purpose of providing combined movement of arms and legs for patients.

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