Research on Control System of Horizontal Lower Limb Rehabilitation Robot

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Abstract: The horizontal lower limb rehabilitation training robot is a medical robot used in the field of lower limb rehabilitation. With the advent of an aging society, the number of groups with lower limb function loss due to moderate stroke diseases is becoming larger and larger, and traditional rehabilitation training is far from satisfying people's need for rehabilitation.

1. Introduction

Walking upright is the most fundamental need for human survival, and it is also a necessary factor for people to ensure their own self-care. However, due to cerebrovascular disease, Parkinson's disease, cirrhosis, spinal cord injury and other diseases damage the central nervous system of the human body, resulting in loss of nerve function. The damaged nerve is difficult to regenerate, causing different degrees of dyskinesia in the limbs of the patient, and can cause paralysis in the severe case. According to relevant data, the incidence of stroke, head injury and spinal cord injury in China is about 2‰, 78.33/100,000 and 20/1 million. It can be seen that these diseases, especially strokes, have extremely high incidence and disability, which are the primary factors leading to hemiplegia. According to statistics, there are more than 3 million new patients with neurological diseases in stroke each year, and 70% to 85% of the first stroke patients have hemiplegia sequela after surgery and drug treatment. In addition, the recurrence rate of stroke accounts for about 25%, and the recurrence of stroke is more critical to the damage of the nervous system. The energy and resources spent on rehabilitation are more and more, and the economic loss caused by each year is more than 300. Billion yuan. The patient loses the independent walking function of the lower limbs, and the quality of life is seriously degraded, which not only causes physical and psychological problems for the patient himself, but also brings great burden to the family and society, forming a social problem.

2. Difficulties in the technical training of lower limb rehabilitation training robot

At present, the control strategies of lower limb rehabilitation training robots are relatively simple, and most of them are robots to drive the lower limbs for rehabilitation training according to the established trajectory. During the rehabilitation process, the patient's condition and ligament stretching degree are different from person to person. The patient's feelings are not considered when setting the training mode and training intensity, and the use of the rehabilitation training robot is limited. In order to improve the wide-ranging and adaptive functions of lower limb rehabilitation training robots, various universities and research institutes at home and abroad have proposed various control theories to improve the performance of robots. However, most of them are experimental in terms of research status. Further verification and correction is required during the room phase. Among them, how to accurately reflect the patient's active rehabilitation awareness to rehabilitation training is the most difficult place, the current position-based impedance control, force-based impedance control, force/position compliance control, auxiliary force field/resistance field thinking, It is the main method proposed by experts to solve these problems. Some experts have proposed the control thought based on EMG signals and EEG signals, but the conclusions on the relationship between patients' condition and active exercise will be one-sided.

In the process of assisting patients in rehabilitation training, in order to ensure the safety of the

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patients in rehabilitation training and objectively evaluate the rehabilitation effect, it is necessary to record, feedback and analyze the movement information of the lower limbs of the patients in real time. Therefore, it is necessary to increase the detection sensor on the robot body and the patient itself to provide reliable information to the physiotherapist or medical staff. At present, the research fields in the field are mainly functional electrical stimulation, myoelectric signals, and EEG signals. Relatively speaking, research based on surface electromyography signal acquisition and processing has achieved certain results. Using the acquired surface EMG signals, the patient's muscle characteristics can be analyzed and the patient's motor intent can be obtained, and the patient can be trained in rehabilitation. But how to ensure the accuracy of the collected signals is a difficult technique.

3. Horizontal lower limb rehabilitation training robot overall control scheme

At present, the control of rehabilitation robot mainly includes classical PID control, force impedance control, position impedance control, force/position hybrid compliance control, electromyography, EEG signal identification control and virtual field, etc., while the active and impedance training modes are currently in use. A common control strategy is impedance control. The ideal resistance mode should be the autonomous movement of human beings. The robot exerts resistance and follows the movement of people according to the consciousness of human autonomy. How to convey the consciousness of human autonomy to the robot is the key to the problem. In theory, if you want to determine the patient's autonomous movement intention, you can directly judge the patient's own surface muscle signal or brain nerve signal. The use of myoelectric signal meter to extract the patient's active rehabilitation consciousness and predict the patient's exercise intention is a common way in rehabilitation training. Many research institutions at home and abroad have begun to study this research. In the upper body rehabilitation training robot developed by Harbin Industrial University in China, the surface electromyography signal of the limbs of the hemiplegia patients is collected by the electromyography signal. The algorithm of the neural network can be used to identify the upper limb movement intention according to the surface muscle signal, which is used to drive the robot movement. To enable the robot to realize the auxiliary movement and follow-up motion function in the true sense. In addition, Tsinghua University developed a brain-computer interface based on EEG signals, directly collecting the patient's cranial nerve motion signals and recognizing them as motion, as the expression of the patient's true motor intention is used to drive the rehabilitation robot movement.

According to the functional requirements of the rehabilitation training of the horizontal lower limb rehabilitation training robot and the determined rehabilitation mode, and referring to the research program of the lower limb rehabilitation control strategy at home and abroad, on the basis of this, the overall idea of the robot control strategy is determined, and the overall Control plan. The goal of the control system is to be able to control the operation of the robot, to ensure the safety of the patient in the rehabilitation training, and to switch the rehabilitation cycle, rehabilitation speed, rehabilitation action, etc. according to the patient's own situation. Also, increase the flexibility of the control system. Taking into account the above factors, the control of the horizontal lower limb rehabilitation training robot mainly includes four parts: the upper computer control center, the robot movement, the human lower limb movement and the active rehabilitation consciousness of the human.

The upper control center judges the patient's rehabilitation needs according to certain criteria through the measured surface EMG signal, and automatically matches the rehabilitation mode. According to the matching rehabilitation mode, the motion control program is programmed by the motion control card and Visual C++ to control the movement of the robot, so that the robot can drive the lower limbs of the patient to perform rehabilitation exercises. It is also possible to control the patient's condition according to the physical therapist or the medical staff, and set the rehabilitation action by himself, and then the robot drives the patient to perform the rehabilitation training of the set action.

4. Horizontal lower limb rehabilitation training robot control system

The selected motion control card (GTS-800-PV(G)-PCI series) is composed of DSP and FPGA, enabling high-performance control operations. This motion control card is hosted by IBM-PC and its compatible machine. It provides a standard PCI bus and can control the movement of eight axes at the same time. For the four-degree-of-freedom horizontal lower limb rehabilitation robot structure designed in this paper, it is completely Satisfy the use requirements, and the research in the next step can always meet the requirements of the addition of degrees of freedom. The control cycle defaults to 200 microseconds, the analog output is ±10V, the pulse output frequency is up to 1MHz, and the encoder input maximum frequency is 8MHz. The motion control card provides a library of functions such as the C language and a Windows dynamic link library to implement complex control functions. These control functions can be integrated with application modules such as data processing, interface display, and user interface required by their own control systems to build control systems that meet specific application requirements. At the same time, the A/D module of the motion control card itself can read the status directly through the language provided by it, and the application is convenient. At present, compared with control strategies such as nonlinear control, fuzzy control, and BP neural network, the classical PID algorithm is the most widely used in motor control. In terms of control effect, PID algorithm control still has its own advantages. The PID control model is easy to set up, and only three parameters of proportional, integral and differential can be properly set to complete the general control purpose. The control algorithm of this paper adopts the control algorithm of PID+speed feedforward (Kvff)+acceleration feedforward (Kaff). By adjusting the corresponding parameters, the precise control of the robot is realized. The motion control card provides a servo filter with PID+speed feedforward (Kvff) + acceleration feedforward (Kaff). By adjusting the corresponding parameters of the PID and feedforward terms, accurate and stable control can be achieved for most systems. . Compared with the traditional PID control, PID+ speed feedforward (Kvff) + acceleration feedforward (Kaff) control provides pre-feedback of speed pre-feedback and acceleration based on PID control, and its control effect is better. Traditional PID control.

The role of the proportional link Kp: According to the "the size of the deviation" to operate, the deviation signal of the proportional reaction control system can be adjusted smoothly, the effect is timely and no hysteresis, and it can effectively overcome various disturbances, which is the most basic regulation law. When Kp increases, the proportional adjustment effect is enhanced. At this time, the speed of the system is increased, and the control accuracy is improved within a reasonable range. However, the Kp is too large, resulting in a decrease in the stability of the system. When Kp is decreased, the parameter residual is adjusted. The smaller, and the slower the Kp system, the increased adjustment time of the system. The role of the integral link Ki: According to the "deviation exists", the main purpose is to eliminate the static error, and its output change is proportional to the integral of the input deviation to time. As long as there is a deviation in the system, the integral control function is continuously accumulated, and the output change will stop only when the deviation completely disappears. The strength of the integral action depends on the integral time constant TI, the larger the TI, the weaker the integral action, and vice versa. When TI is reduced, the integration speed is increased and the adjustment is enhanced. However, the number of oscillations in the TI system is too small, and the stability is deteriorated, so the TI value should be moderate. Since the integral adjustment is slow when used alone, the adjustment action always lags behind the change of the deviation signal, so it is usually combined with the proportional adjustment to form a proportional integral (PI) adjustment law. The role of the differential link Kd: according to the "deviation change speed", the rate of change of the reaction deviation signal, and can introduce an effective early correction signal in time to prevent the parameter being adjusted before the value of the deviation signal becomes too large. All changes, with the role of "advance" adjustment, can comprehensively improve the dynamic performance of the regulation system. When Kd increases, the differential adjustment effect is enhanced, but Kd increases the overshoot and adjustment time of the system, and the stability of the system becomes worse. When the differential term is set properly, the overshoot and dynamic error can be reduced. Increasing the stability of the system has a significant effect on improving the dynamic performance of the system. Since the differential adjustment does not work for pure hysteresis, once the deviation change stops, the differential action disappears, so it cannot be used alone, usually combined with proportional adjustment or proportional integral adjustment to form proportional differential (PD) or proportional integral derivative (PID) adjustment. law.

5. Conclusion

In this paper, a large number of data are searched and summarized for the research status of lower limb rehabilitation training robots at home and abroad. Based on rehabilitation medicine, the theory of clinical rehabilitation and sports re-learning of lower limb hemiplegia caused by stroke has been studied carefully. On this basis, the requirements of robot design for lower limb rehabilitation training are summarized, and the horizontal lower limb rehabilitation training mode is proposed: passive training and independent rehabilitation training. And on the mechanical system body of the horizontal lower limb rehabilitation training robot that has been built, the overall control scheme of the lower limb rehabilitation training robot is proposed.

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