The research of fractional order control system

based on surface EMG signal

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Abstract: With the development and integration of the subjects such as rehabilitation medicine, mechanical electronics and control theory, the related theory and technology of rehabilitation robot have important research value in the field of clinical medicine disease diagnosis, rehabilitation medicine, muscle function evaluation and artificial limb control. Quantitative identification of joint motion information and the quantitative model of sEMG and joint angle signal are established in this paper through the data acquisition and analysis of surface EMG signal (sEMG) and joint angle signal. The signal of sEMG are input into the   quantitative model of sEMG , and then output the prediction angle of the joint, identify the movement intention, carry out motion planning, rehabilitation robot driven by permanent magnet synchronous motor in accordance with the movement of the patient's intention to drive the upper limb rehabilitation training. In order to achieve high performance speed control of AC permanent magnet synchronous motor, the fractional order proportional integral controller is proposed which can satisfy the stability and robustness of the system. Compared with the integer order PID controller, the fractional order PID controller has two adjustable parameters λ and μ which can achieve better control performance.

Introduction

Upper limb rehabilitation robot system is a special robot system in the field of clinical medicine which produces a complementary or alternative doctor to complete the limb rehabilitation training which has opened up a new technical way for upper limb hemiplegic rehabilitation, and makes up for the clinical treatment of the movement of the problems mentioned above. Upper limb rehabilitation robots break the limitation of doctor-patient between one to one including the physician from heavy and repeated training mission to make it more focus on the treatment improvement, and making it possible to focus on medical and remote rehabilitation .In addition, the rehabilitation robot through intelligent human-machine interface can provide different strength in different period of rehabilitation patients. Therefore, the research and the development of upper limb rehabilitation robot system will promote the medical and engineering resources complementary, which is the important practical significance to the development of the social progress of rehabilitation.

Rehabilitation robot system based on sEMG

Because of the complexity of the electromyographic signal producing mechanism and the complex relation between the ectromyographic signal and the autonomous motion control system of the human body, which makes the relationship between sEMG and arm motion difficult to determine. The process of sEMG for pattern recognition can be expressed as the process of electromyographic signal collection, signal preprocessing, feature extraction and pattern recognition. Firstly extract the characteristic value by analyzing the electromyographic signal , and then the characteristic value are input the mode identifier for identification. In order to realize the gesture recognition accurately, feature extraction and pattern recognition is the key to the whole system..
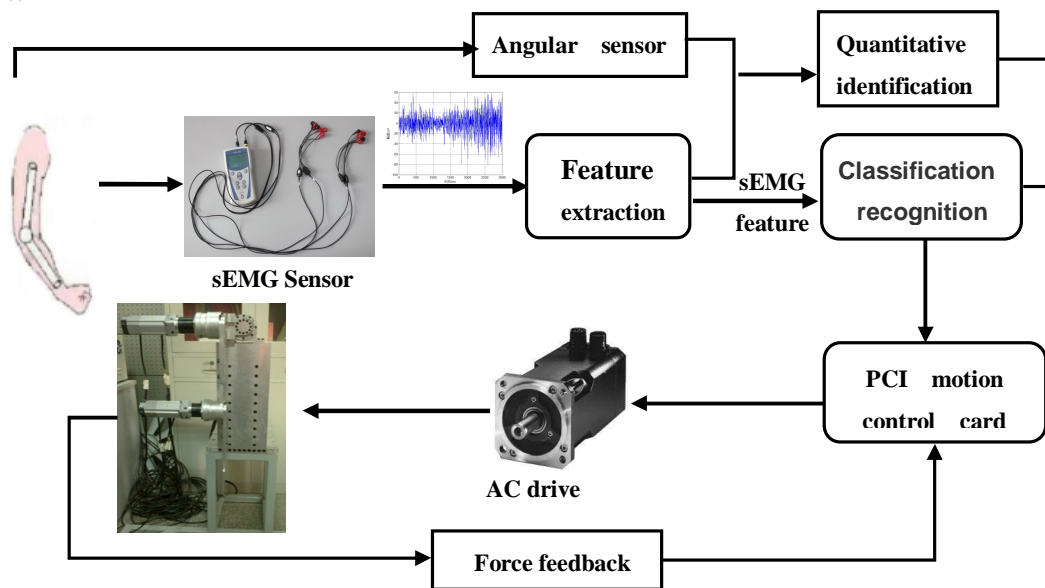

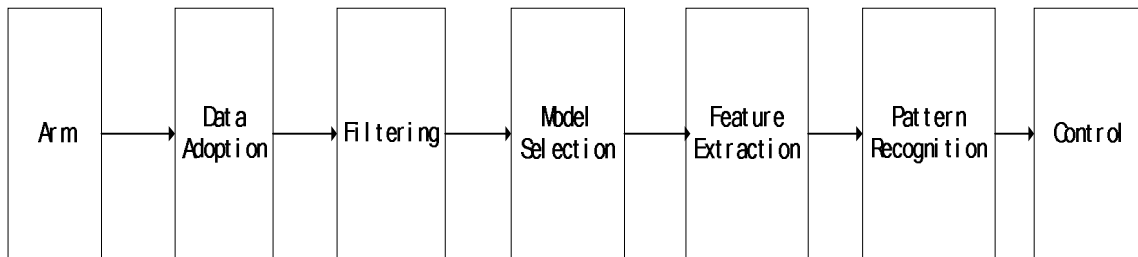Figure 1   The system principle diagram of Robot based on sEMG

Figure 2   The flow chart of signal processing

The design of Fractional order control system

Fractional order calculus is the basis of any non integer order problem,which is the an integer order differential and integral calculus to promotion. Fractional order calculus for the basic operation of the operator, and among them a and t is the upper and lower operator, α is the order for calculus. It has the following form:

$$_a D_t^a = \begin{cases} d^a / d^t & R(a) > 0 \\ 1 & R(a) = 0 \\ \int_a^t (dt)^{-a} & R(a) < 0 \end{cases}$$

R(α) is the real component of α. Observation on the type, When R(α)>0, $_aD_t^a$ is fractional order differential; When R(α)<0, $_aD_t^a$ is the fractional order derivative integral; When R(α) is an integer, $_aD_t^a$ is the integer order differential and integral calculus, Accordingly, Fractional calculus in essence is a special case of fractional calculus.

With fractional order $PI^\lambda D^\mu$ the system structure of the controller ,as shown in Figure 3, in the figure, R(s) is the reference input, E(s) is the error, G(s) is the controlled object transfer function, G(S) is the fractional order controller, Y(s) is the system output.
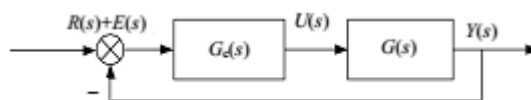

Figure 3　　Fractional order control system structure

Permanent magnet synchronous motor is a multi-variable, strong coupling, nonlinear, variable parameter of complex object, in practice, due to the interference and the influence of uncertain factors such as internal perturbation,the traditional PID controller is difficult to meet the requirements of high performance control.Fractional order $PI^\lambda D^\mu$structure diagram of the control system is shown in Figure 3:
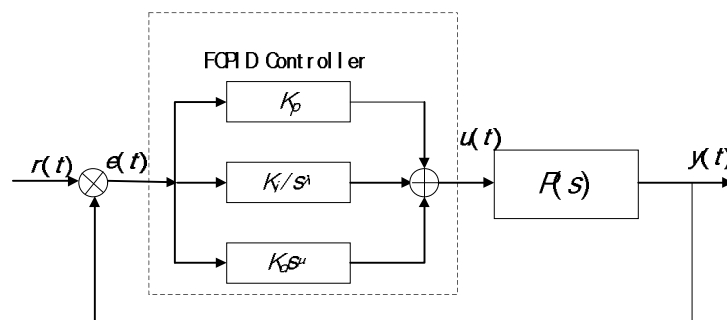

Figure 4　　The structure diagram of the FOPID control system

(1) Integral order λ changes impact on the system

In the fractional order $PI^\lambda D^\mu$ controller, when the integral order λ is small, fractional frequency domain controller amplitude-frequency characteristic curve slope is small to low frequency, smaller peak amplitude frequency characteristics, wide frequency band, the system has good stability and more quickly response. In the time domain the step response overshoot is small amount with short rise time and adjust the time. The value of the integral order λ increase gradually, the integral action of the control system strengthen gradually, System step response in time domain have larger amount of overshoot, rise time and adjust time were significantly longer.

(2) the differential order μ changes impact on the system

In the fractional order $PI^\lambda D^\mu$controller, When the differential order μ is small, for linear system amplitude frequency characteristic curve of low frequency and gain a lot, the location is very high, the fractional order control system under the condition of satisfy the stability, the steady-state error is small, the dynamic response of high precision, but the system of amplitude frequency characteristic curve of frequency range is too wide, system overshoot and overshoot time increased. Differential μ order time is too large, the amplitude frequency characteristic curve of spectrum

slope becomes steeper, the closed-loop system will be hard to stability. So, in order to make a fractional order control system is of good control effect, μ should be within the scope of the appropriate values.

Conclusion

In this paper it is Compared with the traditional PID controller integral link of fractional order PIλDμ integral compensators λ can within the scope of (0, 2) any values, the fractional integral link phase frequency characteristics of lag Angle between 0 and 180 ° any change, make the system stability and dynamic performance can improve the system steady precision; Compared with the traditional differential PID controller link, the differential order μ can be arbitrary value (0, 2) scale, the fractional integral link phase frequency characteristics of lag Angle between 0 and 180 ° any change, in order to appropriately increase the system damping, is the control system has better control effect. By introducing fractional $PI^\lambda D^\mu$controller can change the frequency domain response of the control system, thus it can be more flexible to design controller, and the fractional order $PI^\lambda D^\mu$controller can improve the stability of the control system with better robustness.

Acknowledgements

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