DESIGN OF TREADMILL CONTROL SYSTEM BASED ON COS-II AND PID CONTROL METHOD

XU Lei
Xi’an Physical Education University, Shaanxi, China
E-mail: xulei056@163.com

Abstract: Among numerous fitness equipments, treadmill is popular because of the advantages of saving space and not being affected by environment. And the popular of treadmill promoted it development. Electric treadmill, the new-type exercise equipment that combined multiple disciplinary theory and technology, is becoming the main trend of treadmill development. Thus, the research and development of new-type electric treadmill has great importance for people’s health and for exercise equipment market. Neural network and PID control method were studied to determine the PID control method based on BP neural network. Then, the hardware system of electric treadmill was designed by dividing the system into master board and function board. Innovatively, COS-II, embedded real time operating system were chosen as the target platform. Tasks were designed according to the targeted functions of electric treadmill. This is a new and successful attempt to design electric treadmill control system.

Keywords: embedded real time operating system; COS-II; PID control method; electric treadmill; exercise

1. Introduction

It is important for everyone to keep health as healthy body is the base for working and living. And take appropriate physical exercise is one of the important way to get healthy[1]. According to the research of General Administration of Sports of China, the percentage of urban and rural residents who see physical exercise as part of their daily life has obviously increased compared to year 2007and the average sports consumption level has increased as well which indicated Chinese people improved their value, awareness and activeness of physical exercise [2-3]. However, in the modern fast living, time and place for rural residents to take physical labor and exercise are gradually decreasing, and this lead to the decreasing of exercise amount, quite a lot people are constantly keep in the sub-health state.

Creation and development of treadmill increases people’s exercise. The development of treadmill may trace back to 1980s, and become popular since then. Now, it is the 4th generation. With lots of improvement, treadmill achieved add shock mitigation system, entertainment system and natural environment create system based on the fundamental running function, which to some extent surpassed traditional outdoor running[4-5]. Electric treadmill is a significant branch of treadmill, it owns the advantages of saving space and not being affected by conditions that solved the problem of exercise time, space and also people’s unwillingness to contact the bad air outside[6]. At present, the most popular electric treadmill can divided into professional gym type and household type according to its using place. And the current speed control system are a d.c. speed regulation system, a.c. servo drive system and non-brush d.c. Motor speed control system[7]. In the design, we choose non-brush d.c. Motor speed control system and combined with embedded real time operating system which has widely used in different industries for its merits of rich service interface, high reliability and support capacity[8-9]. In the design, we creatively applied COS-II embedded real time operating system to control system of electric treadmill so as to make up for the disadvantage of Wince operating system hard to be on demand , while Linux operating system are complicated and hard to develop.

2. Establishment of speed control scheme and control method

2.1 Basic principle and structure of neural network PID controller

BP neural network possesses the non-linear mapping ability, generalization ability and fault tolerant ability[10], while traditional PID controller have the merits of high robustness and capacity of resisting disturbance, so BP neural network PID controller combined both of their advantages, ensuring control precision when improving the system response speed and robustness[11]. Moreover, BP neural network combined with traditional PID control can effectively solve the problem of PID control’s difficulty to determine parameters, and quickly an optional control law of P, I, D control parameters. The self-learning PID control principle of parameters KP, KI, KD based on BP neural network is: neural network output state determine parameters, and quickly an optional control law of P, I, D control parameters. The self-learning PID control principle of parameters KP, KI, KD based on BP neural network is: neural network output state determining KP, KI, KD to ensuring optimal control precision when improving the system response speed and robustness[11]. Moreover, BP neural network combined with traditional PID control can effectively solve the problem of PID control’s difficulty to determine parameters, and quickly an optional control law of P, I, D control parameters. The self-learning PID control principle of parameters KP, KI, KD based on BP neural network is: neural network output state corresponding to the three adjustable parameters of PID controller KP, KI, KD, neural network use the self-
learning ability to continually adjust weighting coefficient, thus in some stable state, it corresponds a kind optional control law PID control parameters. Figure 1 is the structure picture of neural network PID, mainly include two parts, traditional PID controller and neural network.

The main function of neural network is to adjust PID controller parameters according system running state so as to achieve the optional performance index[18]. It applies BP neural network to set up self-learning controller and use digital incremental PID controller for corresponding relations between digital input and output.

2.2 Control algorithm of BP neural network PID controller

The BP network here is a simple three-layer BP neural network, just as figure 2 shows: M input nodes, responding system running state such as system input and output of different moment, and do the normalized processing if necessary; Q hidden layer nodes; Three output nodes, corresponding parameters KP, KI, KD. As KP, KI, KD can’t take negative value, the active function of the output layer neuron must adopt non-negative Sigmoid function, while the active function of hidden layer neuron could be symmetrical positive and negative Sigmoid function.

2.3 Non-brush d.c. motor control scheme

The non-brush d.c. motor speed control here adopting the method of rotation speed single closed control. Structure flame is like figure 3. The system is composed of six links, namely, theoretic speed, BP - PID regulator, PWM transform link, drive circuit and speed feedback link.

The input of total speed cycle is the values between speed specified value and feedback value, the value abide by BP - PID regulator to change the PWM duty ratio and control drive circuit action and then change rotational speed of electric motor.

Control algorithm of speed regulator uses PID control algorithm that based on BP neural network. The system take fully use of BP network non-linear mapping capability to approach the mapping relationship which include non-linear system input and output pattern by training neural network.

In actual operation, it applies neural network pattern of offline set-up, online adjustment system, that is, set up systematical neural network pattern according system input and output sample values who determines the weights of neural circuits, and put well settled pattern into actual operation.
Thus, the accuracy of neural circuit pattern will directly influence the practical control effects.

3. The design of hardware control system

3.1 Overall structure and design of hardware

The hardware scheme of electric treadmill control system can be divided into main control board and function board. The former directing all parts work to achieve the function of touch screen control, audio playback and data record for user, and also, send control signals to function board by extending the interface. The latter mainly realize the function of speed motor driver, lifting motor driver and heart rate detection.

The main function of main control board including: realized the keystroke touching function and interface figure display by touching screen interface of external touch screen; using audio module for audio playback and recording; selectively store users’ various parameters about exercising; sending control signals to function board by extending the interface. Main controller of it is Samsung S3C2440, microprocessor chip that widely applied to low cost, low dissipation but high performance hand-held device or electronic product. The designed circuit here applied H1S embedded audio system solution for background music playing and related prompt sound playback. Touching screen, act as human-computer interaction interface, adopted Shenzhen macro-crystalline long electronic co.Ltd 7inch screen AT0707TN83,qua display interface and also qua operation touch to control system.

3.2 Research and design of function board

(1) Non-brush d.c. Motor drive

Adjust running speed is one of the basic function of treadmill, so the speed adjust of non-brush d.c. Motor in treadmill control system is one of the most important part[12].Choose special speed adjust chip when doing electronic motor rotation speed control can not only simplify hardware circuit, but also accomplish higher control accuracy. In the system drive circuit, we choose Japanese Sanyo LB11820M as the non-brush d.c. Motor control chip, packing format MFP30SD.LB18B20M mainly contains three-phrase drive circuit, PWM oscillator, logical circuit, sensor signal amplifier circuit, comparing implement, limited current circuit, thermal protection, low-voltage protection and 12V.5V reference voltage generating circuit etc., it can directly apply PWM to drive three-phrase non-brush d.c. Motor and can achieve the control of electronic motor position inversion. The electronic motor born with three hall sensors, their output signal input LB11820M via IN pin, and LB11820M acquiring correct high-low drive input temporal sequence according to signal attend time and order.

(2) Heart rate detection circuit

Heart rate detection device hand type TM998 heartbeat detection module here is selected from Shenzhen Longxianghongda electronics co.LTD. and it used ECG principle while working. Heartbeat can produce electrical physiological change and transmit to the surface. By placing electrodes on human skin, TM998 measures electric potential difference, obtain heartbeat signal. It is important to note TM998 module will have tens of microseconds to hundreds of microseconds sharp wave that need filtering process. And heart rate detection circuit schematic diagram shown in figure 4.

Fig. 4 Heart rate detection circuit schematic

(3) Lifting motor control circuit

The lifting actually is the two-phrase motor, while operating there will produce elliptic rotating magneto motive force between motor air, and then rotating the rotor[13].Motor owns three lead, red, white and black and applies relay to realize the winding switching. The actual capacity is 250AC/3A,coil voltage is 12VDC.Lifting motor control circuit schematic is shown in following picture.

Fig. 5 Lifting motor control circuit schematic

4. Design software for treadmill control system

4.1 Transplant μC/OS-II

μC/OS-II is multitask real-time kernel provided by Micrium company, which is suitable for various microprocessors [14]. μC/OS-II is featured open source code, transplantable, curing and tailoring. The kernel is perceptibility. By adopting μC/OS-II, 64 tasks can be handled at most. Besides, because running time of most of the function references and services are identified, every task is functioning in individual stack space. This system is reliable [15] and can interrupt management because it provides multiservice such as semaphore, mutual exclusion semaphore data, event flag, message
mail boxes, message queue and etc. Transplantation is considered when designing μC/OS-II system, thus most code of μC/OS-II is written in C language. Except code concerning processor hardware is written in assembly language because register can be read and write by μC/OS-II only in assembly language. There are some prerequisites for compiler and processor if μC/OS-II is to be transplanted. For example, compiler should generate re-enterable code if needed. Thus, when developing, ADS compiler and ARM9 processor were used. When transplanting, documents relates to processor have to be changed, thus three documents includes OS_CPU.H, OS_CPU_A.S and OS_CPU_C.C have to be changed.

4.2 Design the main modules tasks

(1) Tasks related to touch screen
Touch screen is an input interface and a display interface [16]. There are two tasks related to touch screen, Touch_Task and Disp_Task. Touch_Task is used to analyze the coordination position of each operate in order to get the corresponding key values. Corresponding messages were sent to different tasks according to the key values. Key values can be used to start and stop tasks, broadcast, pause and record audio, accelerate and decelerate speed, quick access setup for speed, increase and decrease slope and quick access setup for slope. Disp_Task is a program used to explain the messages. When there are short messages in DISP_QMesgTbl, the latest message is read by Disp_Task to separate the command code and data. The display screen is updated by the Disp_Task using the command code and corresponding date.

(2) Tasks related to heart rate test module
Heart rate interrupt service subroutine and Heart rate sampling task (HrSmp) are two tasks involved in heart rate sampling module.

(3) Task related to speed motor drive module
The interrupt service subroutine, speed sampling task (SpdSmp_Task) and PWM task (PWM_Task) were three tasks involved in this module. Figure 8 and 8 show flow of the interrupt service subroutine and SpdSmp_Task.
PWM_Task is a periodic task with dispatching cycle of 20ms, which needs to acquire set value and measured value at the same time. PWM_Task would change data with Touch_Task and SpdSmp_Task using Spd_Data, the global structure variables. Spd_Data is made up of set value and measured value of speed. Based on these two values, PID algorithm was used by PWM_Task to change value of TCNTB0.

(4) Tasks related to lifting motor driver module

Slope sampling task (IncSmp_Task) and Slope adjustment task (InclAdj_Task) are involved in lifting motor driver module. Below figure 10 shows the flow of Slope sampling task. InclAdj_Task was used to adjust slope. After received messages from Incl_QMbox, InclAdj_Task adjusts the slope by absorption or close the lifting motor replay according to messages. When the measured sloped values reaches the set value, IncSmp_Task will be pended by itself and waiting for messages from Touch_Task.

(5) Task related to audio module

Audio recording task (Recd_Task) and Play_Task are involved in audio module. And both tasks are oriented to IIS interface. Messages format type in mailbox is WaveFmt, and this mailbox is used by Touch_Task to inform Recd_Task to perform. Audio data obtained by sampling of Recd_Task are sent to SDRW_Task or Play_Task through IIS_QMesg message. Below figure 11 shows the flow of Play_Task.

5. Conclusions

After studied the treadmill development, µC/OS-II system is introduced to software control system of electric treadmill, because Wince operating system is difficult to customization and Linux operating system is complicated and difficulty in developing. Based on PID control method of BP neural net, embedded real time operating system C/OS-II was taken as target platform. Hardware and software structures for electric treadmill are designed. This is innovative in designing control system of electric treadmill.

6. References:


BRAND:
SMART MECHATRONIC - Competitiveness,
performance and high quality through
HIGH-TECH MECHATRONIC PRODUCTS