Acta Technica 62 No. 3A/2017, 149–156

Research and design on boxing-teaching robot of embedded system and pressure sensor

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Abstract. As an exercise to enhance physicals effectively, boxing is very popular. To meet market requirement of measuring punching power and interacting with boxers, boxing-teaching robot is designed based on embedded system and pressure sensor. The design process is introduced from three aspects - hardware design, embedded platform setting-up and software design. Processor S3C2440 and embedded Linux operating system are chosen and LCD touch screen is used for man-machine interaction. For setting up embedded platform, software development process and operating system of embedded Linux platform are adopted and cross-compiling environment is established. Qt/Embedded is used to design application program. Thus, five modules have been designed. Embedded database SQLite is used for data storage. The designed boxing-teaching robot promotes boxing teaching.

Key words. Boxing robot, punching power, S3C2440, embedded system.

1. Introduction

The origin of boxing dates back to a long time ago. When boxing, boxers keep jumping and think fast and thoughtful for every punch [1]. Thus, both locomotive organ and brain are trained, which results in strengthened strength and improved reaction capability [2]. However, facilities of boxing are not popularized domestically. Most boxing equipment in gym is boxing training dummy of tumbler or in shape and figure of whole human body. Those traditional boxing equipment is only for practicing punching and punching power and speed are not measured by it. Thus, it is hard for a boxer to get a well training [3]. Boxing equipment abroad is similar to that of home, which is only superior in durability and punching hand feel [4].

Electronization of sports equipment is greatly promoted by the developed modern science and technology, especially information technology and micro-electronic technique [5]. Experts and scholars at home and abroad have studied sports equip-

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ment electronization, most of which is on ball game electronization. For example, Y. L. Liu et al. [6] designed network communication of soccer robot achieving information passing and sharing among robots. C. Tang et al. [7] studied an algorithm of moving basketball robot based on color space and object shapes. However, there have been few studies on boxing equipment electronizing. Thus, boxing-teaching robot is designed based on embedded system, pressure sensor and computer communication technology. And its software and software have been designed.

2. Hardware design for boxing-teaching robot

2.1. General structure of system

Overall structure of the designed boxing-teaching robot was made up of boxing training dummy and man-machine interaction module. Boxing training dummy consisted of punching airbag of head and chest, corresponding pressure sensors (on the head and chest), air pump for airbag, mechanical arm, drive motor and photoelectric sensor. Man-machine interaction module was made up of LED panel, control box and voice broadcast. In terms of functions, boxing teaching system was divided into five parts such as CPU, AD data acquisition, auto-punching, air pump control and man-machine interaction. Block diagram of system functions is shown in Fig. 1.

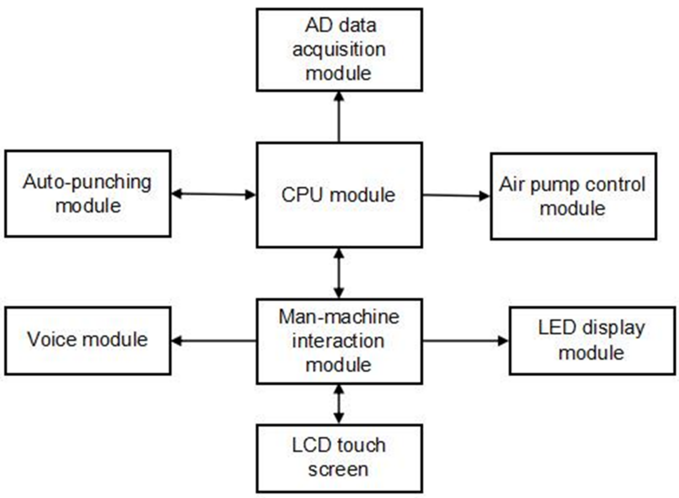

Fig. 1. Block diagram of system functions

2.2. Specific module design

S3C2440 processor of ARM9 development board was selected for CPU module. Almost all hardware components of this system were provided by this development board. Besides, this development board can operate the needed embedded Linux operating system. The man-machine interactive module was made up of LCD touch screen, LED result display and voice broadcast. 3.4 inches ultrathin liquid crystal touch screen with resolution ratio of 320×240 and TFT true color from Samsung company were chosen, which was characterized by no heat, low-power dissipation and long working hours. Voice chip UDAl341 was used in voice module. Function of voice module was driven by compiling UDAl341 and cross compiler arm-linux-gcc3.4.1 was used here. AD data acquisition module was made up of pressure sensor and ADC converter. MPX5100SERIES pressure sensor was selected, for which 5V direct-current power supply and 100 kPa measurement range was needed. ADC converter of S3C2440 was used by AD converter. Auto-punching module was made up of photoelectric senor, direct-current dynamo, feedback switch, signal acquisition and control circuit. Signal acquisition circuit of photoelectric senor is shown in Fig. 2. Motor control circuit was made up of CD4093, optocoupler 4N26 and high-power MOS tube IRF3025. Among them, pin 1 and 2 and pin 12 and 13 of chip CD4093 were connected to pin 30 and pin 28 of processor S3C2440 respectively to control and simulate left and right punch. Mainly, air pump control module is used to re-inflate air bag, which schematic circuit diagram is shown in Fig. 3.

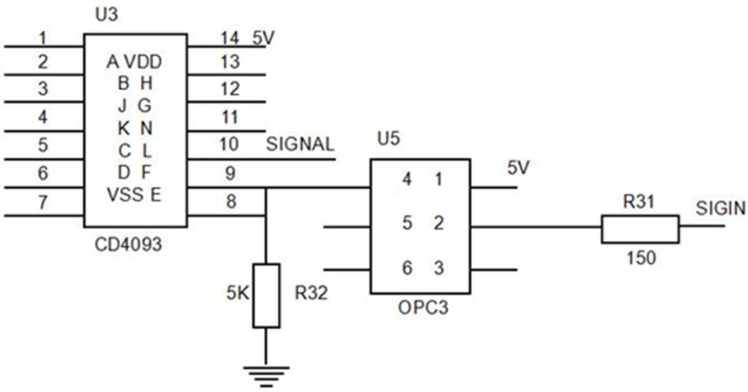

Fig. 2. Signal acquisition circuit of photoelectric sensor

3. On system of embedded software

3.1. *Software development process and operating system of embedded Linux platform*

Embedded software development process of Linux is divided into five parts: embedded processor and hardware platform selecting (according to users' requirement) → Boot Loader porting → kernel tailoring and compiling → appropriate file system generating → application development and system testing. Utu Linux operating system provided by YangChuang TeK featuring small kernel, high efficiency and open sources was selected. This operating system was designed based on processor supporting MMU (memory management unit). It was easy to tailor the embedded

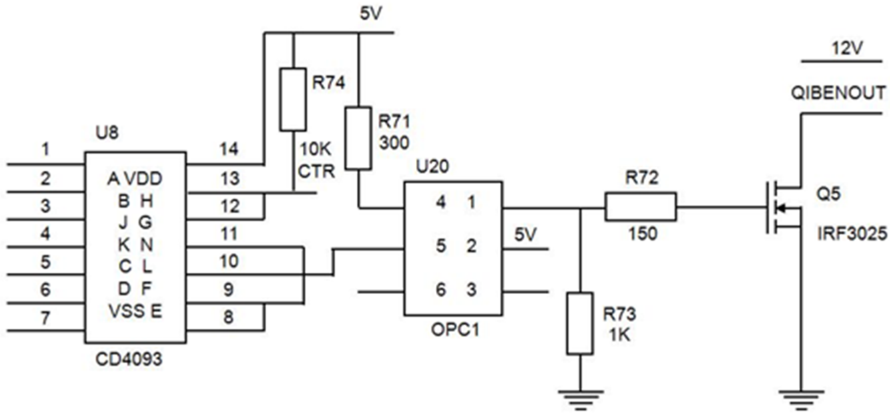

Fig. 3. Control circuit of air pump

operating system because of its dynamic module loading. Those functions related to utu Linux were also used: controlling development board with command, transmitting data through PC computer and development board and operating program automatically.

3.2. Cross-compiling environment establishment

When developing embedded system, apart from the existing development board of S3C2440 processor, a host machine with Linux operating system was needed whose corresponding development board was target board. Cross compiling was used because processors of host machine and target board were incompatible. Development environment of embedded system is shown in Fig. 4. Two things have to be done to establish a cross-compiling environment: for target machine, install Linux operating system and Qtopia bank. For host machine, install Linux operating system and tool chain arm-linux-gcc-3.4.1 and arm-linux-gcc-3.3.2 of cross compiling. Besides, Linux system sound code and Qt sound code of target machine and host machine were the same. Apart from embedded Linux operating system, Bootloader, kernel and file system provided by YangChuang TeK was selected for target board, which needed some modifications before application, such as selecting touch screen supporting 290×320 for compiling Bootloader and kernel and using touch screen as input equipment for generating file. When establishing environment for host machine, arm-linux-gcc cross compiler should be added to host machine firstly. Then, compile kernel tree which is the same version of target machine. Finally, Qtopia bank file of target machine was added to host machine [8].

4. Software design of boxing-teaching robot

Embedded system software was the key to design boxing-teaching robot, which including AD data acquisition, UI (user interface), auto-punching, SQLite database and result display. Those five software modules were realized through multi-process.

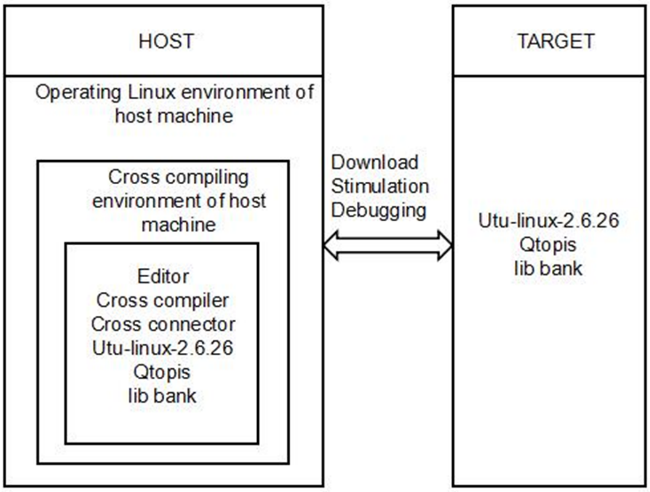

Fig. 4. Schematic diagram of embedded cross development

AD data acquisition and processing module was made up of pressure data acquisition and data processing. Data acquisition was an independent progress in the system, which computedpunching power by dynamometry, displayed it by LED display screen then wrote the power value in message queue. Data processing was mainly for converting the pressure signal collected by pressure sensor into punching power value.

Result display module was made up of voice broadcast and punching power displaying. Voice broadcast received message sent by UI module by message queue then voice broadcast it correspondingly. Punching power display function was made up of a group of Nixie tubes which was made up of LED and controlled by single chip. Single chip received punching power data that sent by ARM development board with serial port. After verified effective, those data were displayed on Nixie tubes. Punching power display module was made up of transmitting end and receiving end. Transmitting end was operating on ARM development board while receiving end was receiving data through R232 serial port and displaying it on LED display screen. Display module of punching power is shown as block diagram in Fig. 5.

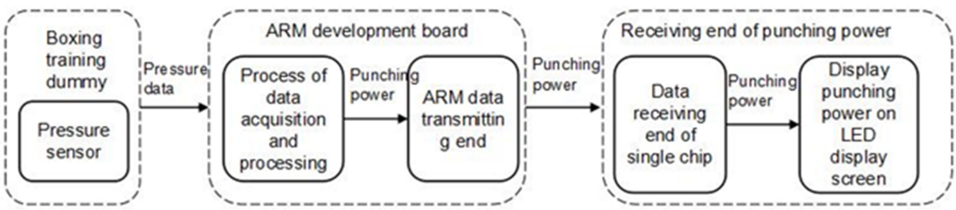

Fig. 5. Block diagram of power display module

Auto-punching module was made up of signal acquisition program of photoelectric sensor and punching control program. Signal acquisition program of photoelectric sensor was used to identify whether there was human within the effective range before boxing training dummy. After acquired signal, rand0 random function was used to determine whether simulate punching or not. If it was yes, left punch or right punch. Pause time after punching was randomly determined by the system.

Database SQLite module was used to save detailed data of boxer's each punching under fast punching module. This module was made up of data storage and data query. Data storage was used to record detailed data of each effective punching including punching position, punching time, total time and the minimum threshold value of power. Data query was used to query the data base and provide the needed data according to requirement when under demonstration mode.

In UI user interface module, LED touch screen was used for man-machine interaction, through which user can operate system. In order to make it easier, the whole system was divided into "mode selection" and "result display". There were three different modes – pressure testing, strong punching and fast punching. Result display interface showed total punching time, each punching time, total number of effective punching, each punching power and total number of punching.

5. Conclusion

The robot designed is a multi-functional integrated system with excellent hardware equipment and software platform. Punching power is computed by pressure sensor when boxers punch air bag. Thus, it is displayed in real time. Functions such as abundant voice broadcasting and practical randomly punching increase man-machine interaction, which makes the system instructs boxers well.

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Received May 7, 2017