Design of Control System for Dust - collecting Robot Based on DSP

Zhang Wei
Automation and Electrical Engineering Institute of Linyi University
Linyi，Shandong,China
Email:zhwei369@163.com

***Abstract*—With the rapid increase of labor cost in domestic service industry, it provides a powerful driving force for rapid development of service robot. Vacuum cleaner Robot as a service robot, you can replace the people to clean rooms, workshops, walls and so on. In this paper, the structure and function of the robot's measurement and control system, the type and function of the selected sensor are introduced. The structure of the motor control system and the driving principle of the motor are introduced. It can be self-navigation, detection of the wall, the room obstructions and can avoid, can travel most of the room space, you can detect the battery power and autonomy to return to charge, with strong application value.**

Keywords-control system; robot; sensor; DSP; communicate

I. INTRODUCTION

With the aging of the population and the improvement of social welfare system, resulting in a sharp rise in labor costs, labor costs in the domestic service industry compared to a substantial increase in the context of home service robot technology continues to mature, more practical, The cost will be further reduced, the price will be ordinary household consumer electronics products rather, or even cheaper. Therefore, it is expected that the home intelligent service robot will take advantage of leveraging domestic service market, the next 10 years as a high-end home service robot robotic consumer electronics products, will enter the home consumer electronic products directory[1]. Bill Gates once predicted that the robot will eventually enter the home, just like a personal computer as everyone has. Cleaning robot is a kind of service robot, you can replace people to clean rooms, workshops, walls and so on. Indoor cleaning robot's main task is to be able to replace people to carry out cleaning work, and therefore need to have some intelligence. Clean robots should be able to self-navigate, detect walls and obstructions in the room and be able to avoid; can travel most of the room space, you can detect the battery power and autonomy to return to charge, while requiring shape comparison Compact, stable operation, low noise; to have a user-friendly interface, easy to operate and control.

II. ROBOT SYSTEM STRUCTURE AND FUNCTION

In order to make the cleaning robot movement more smooth, to prevent the phenomenon of stuck, the vacuum robot designed to cylindrical or flat cylindrical shape, this design can make it free to enter the sofa, bed and furniture, some corner Are able to clean. Parallel to the ground with a circular chassis is supported by three wheels, left and right sides of the drive wheel, respectively, by the two micro-DC motor directly driven in front of the support wheel for the caster[2]. This shape and wheel layout of the robot makes it easy to turn in situ, greatly improving the walking dexterity, which is more prominent in the smaller space. A multisensor system consisting of collision, ultrasonic, and infrared sensors is used, with an infrared receiver on top of the robot; at the bottom edge of the robot. Every 45 °with a proximity sensor, used to detect the steps to prevent the fall; in front of the robot with a crash sensor, front and left and right with an ultrasonic sensor to detect the surrounding environment. The robot is equipped with a power management system, if the voltage is too low will stop cleaning, and to automatically charge. Robot processor is TI's TMS320LF2407A, it can quickly handle a variety of signals detected by the sensor, and can carry out rapid processing, the robot can quickly make a variety of reactions, the successful completion of the cleaning work.

Robot control system to complete the task: receiving sensors and encoders from the data, comprehensive treatment for cleaning path planning; drive left and right round before walking, cleaning control, vacuuming agencies to complete a variety of underlying control actions; design appropriate man-machine Interface that displays the robot status and running time on the LCD[3]. Therefore, the robot control system includes a sensor module and a motor drive module. Structure diagram of control system is Figure 1.

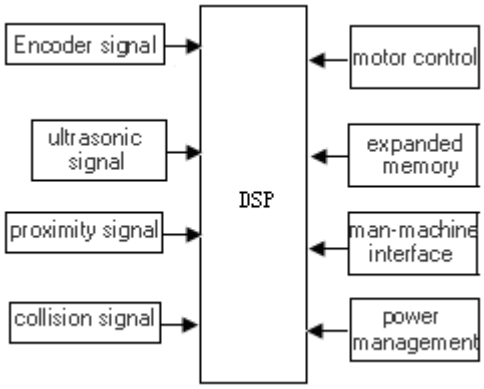

Figure 1. Structure diagram of control system

III. ROBOT HARDWARE COMPONENTS

A. *Microcontroller*

Traditional microprocessors such as 51 series, although the development cycle is short, low cost, but its real-time is not good, difficult to achieve complex control algorithm; In addition, the increase in peripheral circuit data conversion speed, the robot performance is not sufficient Play. Although the emergence of high-speed DSP makes the system modular and all-digital, so that the processing speed of the robot greatly accelerated, the system uses TI's TMS320LF2407A (hereinafter referred to as 2407) DSP chip, which is TI's DSP TMS320 series based on, Digital motor control and design. In addition to the general DSP's improved Harvard architecture, multi-bus structure and pipeline structure and other advantages, it also uses high-performance static CMOS technology, the voltage dropped from 5V to 3.3V, reducing power consumption[4]. And instruction execution speed increased to 40MIPS, almost all instructions can be completed in a single cycle of 25ns. It has the peripherals necessary for motor control applications: 32K on-chip FLASH, 2K single-access RAM, serial peripheral interface (SPI), serial communication interface (SCI), two event management modules (EVA / B), 16 Channel dual 10-bit A / D converter and CAN controller module. Each of the event managers includes the following resources: two 16-bit general purpose timers, eight 16-bit pulse width modulation (PWM) channels, three capture units for external events, quadrature encoder pulse (QEP) . As mentioned earlier, TI's 2000 series of DSP chips for the control area, 2407 of the PWM circuit has a dead-zone generation circuit, designed specifically for the bridge circuit, and the dead-band unit is programmable, making the peripheral hardware The circuit is greatly simplified, therefore, use the event manager PWM function to achieve the DC motor control is very convenient. It is particularly suitable for industrial control and small robot system, to meet the robot controller speed requirements. TMS320LF2407A as the core, the design of simple structure, stable performance of the cleaning robot body system[5].

B. *ultrasonic distance measurement module*

The basic principle of an ultrasonic transducer is to measure the time it takes to transmit and return from the sound wave to the receiver. First, the controller sends a 5μs wide pulse to stimulate the sensor to launch 40kHz high-frequency pulse, pulse issued after 750μs, the pin-level high; when the sensor receives the echo, the pin level is pulled low. From the high side of the width of the signal side to know from the launch to return to the time required for the width of 115μs ~ 18.5ms between. The formula s = vt / 2, where s represents the distance between the sensor and the target; t represents the time to launch to the recovery; v is the acoustic velocity, v = 340m / s. Thus, the distance between the sensor and the obstacle can be known[4]. A probe time of up to 20ms, 5 sensor query is completed, with l00ms, so two adjacent sensors using time-sharing to enable, will avoid mutual interference, and will not affect the speed of the robot. The ultrasonic ranging module KS103 adopted in the design adopts the SLAVE I^2C technology with innovative features. It communicates with the host computer through the standard I^2C interface, does not occupy the MCU timer, and can share the bus with other devices. With the temperature compensation function, high precision, the use of

temperature correction of the ranging command, the highest precision within a short distance of 1mm, the error is 0.152mm / 17cm; measurement of the blind area to a minimum of 1cm, no blind zone; with adjustable filter noise reduction technology, Power supply voltage is subject to interference or noise, you can still work, you can also send 0x70-0x75 a total of six levels of noise reduction instructions on the KS101B / KS103 configuration, effectively suppress the power supply noise on the ranging effect; Mode: with automatic sleep function, the module does not receive the host within 5s automatically enter the sleep command, at any time by the host I2C control instruction wake[6]. The maximum power consumption during sleep is: 500uA / 5.0V.

C. *Infrared Proximity Sensor*

Reflective photoelectric switch is composed of infrared LED light source and photosensitive diode or phototransistor and other photosensitive components, when there are obstacles to block the light can be reflected back, the output is low signal; when there is no obstruction to block, the light can not be reflected back, The output is a high level signal. The close-proximity infrared proximity sensor of the vacuuming robot consists of two groups of the same infrared transmitting and receiving circuit. Each group of circuit can be divided into high frequency pulse signal generation, infrared emission regulation and control, infrared emission driver, infrared receiver and other parts[7]. The infrared light emitted by the emission tube is reflected by the object and then received by the infrared receiving module. Through the internal processing of the internal integrated circuit to return to a digital signal input to the microcontroller I / O port. If the receiver receives the infrared pulse will return to the output low, otherwise it will output high. Through the I / 0 port detection, we can determine the existence of objects. The Si1143 infrared proximity sensor can detect close range of up to 50cm. If a suitable narrow-angle lens and an infrared filter are used in combination, the emission half-angle of the infrared LED is small enough that the emission beam Fully converged. At the same time, the infrared LED emission power is large enough, the maximum range of up to 1m. Si1143 infrared proximity sensor comes with three infrared LED driver, the host MCU can control its function through the I^2C interface, when the infrared emission of the LED is reflected by the proximity of the object is built-in infrared photodiode receiver, and then analog-digital conversion of light Strong signal is converted to digital signal, the calculated value can be compared with the set threshold value, if more than the threshold set the output from the INT interrupt signal to the main MCU, through the corresponding software to achieve specific operational functions[8].

D. *crash switch sensor*

Two slots on the photoelectric switch are distributed in the robot before the left and right to do. Such a layout allows the robot to perceive obstacles in three directions from the front, the front left, and the right, so that different responses are made depending on the direction of the obstacle. When the robot encounters obstacles, the spring under the action of obstacles, inward pressure collision switch swing arm, urging the reed to block the photoelectric switch light, the output low. When there is no obstruction, the reed under the action of the spring to restore the photoelectric switch light is not blocked, the output high.

Among the three sensors, the ultrasonic sensor is used to detect the front and left and right walls, obstacles. Two ultrasonic sensors on the left and the right are placed perpendicular to the walking direction for the walking plan of the robot. The distance between the robot and the wall is set to adjust the walking direction of the robot so that the distance between the two ultrasonic waves and the wall is approximately Equal to the set value, keeping the robot walking along the wall to maintain an appropriate distance, will not hit or away from the wall. The front two collision sensors and an ultrasound used to detect the first half of the environment; contact sensor with a large detection range, the signal without conditioning, taking up less resources, through contact collision, to detect those not detected by the ultrasonic sensor Bar-shaped obstacles such as furniture legs, etc. Proximity sensors are used to detect whether there is a cliff on the ground, in the robot at the bottom of the front, left front, right front and rear of a layout[9]. In addition to the above three sensors, the three wheels are equipped with a normally open switch sensor, when the wheel when the float,

the switch will close, the output low. When the wheels are floating, the robot can be stopped.

IV. Motor Control System

In the low power system, the DC motor has good linear characteristic and excellent control performance, suitable for point and speed control. In order to achieve positive and negative run of the DC motor, only need to change the polarity of the motor power supply voltage. The change in voltage polarity and the length of the run time can be achieved by the processor, while the current that provides the normal operation of the DC motor requires a drive circuit. H bridge drive circuit is the more commonly used driver circuit. Through the DSP to generate different duty cycle PWM pulse, precise adjustment of the motor speed. This type of circuit operates at the transistor saturation or cut-off state, avoiding the transistor in the linear amplification area of the work of the tube, can maximize efficiency; H-type circuit to ensure that the motor speed and direction can be achieved simple control.The Motor drive circuit is Figure 2.

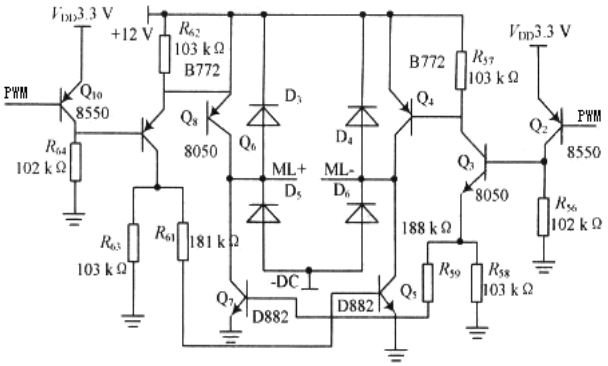

Figure 2. Motor drive circuit

With 2407 PWM output pin, you can control the speed of the motor. This part is mainly to ensure that the robot can move in the plane, while the wheel with the encoder, you can detect the distance traveled[10]. The dead reckoning can realize robot turning, indexing number hypothesis for N encoder robot; controller received pulse number is m; the wheel diameter is D; the distance between the two wheels of the wheel is W, forward distance:

$$S = \pi mD / N \qquad (1)$$

Pose a robot in the environment coordinates is (X (T), Y (T), φ(t)), then the n+1 sampling azimuth angle φn+1 and the n sampling values have the following relationship:

$$\varphi_{n+1} - \varphi_n = \frac{1}{W}\int_n^{n+T} [v_R(t) - v_L(t)]dt = \frac{1}{W}(\Delta S_{Rn} - \Delta S_{Ln}) \qquad (2)$$

V. Conclusion.

As a kind of service robot, the cleaning robot has huge market potential and wide application prospect. With the development of sensor technology and the continuous progress of microprocessors, prices are declining. This paper researches and designs a control system of the cleaning robot based on DSP, not only to meet the practical requirements, and on the basis of not increasing cost for the software provides a good hardware support, provide good technical support for better algorithms and software upgrade.

References

[1] Yun Chao.New Robot Control System [J]. China Information Industry-e Manufacturing, 2015 (6): 22-23.

[2] Liu Lei, Sun Xiaofei, Zhang Yu. Follow the electronic measurement technology [J]. STM32 car design based on intelligent remote control, 2015 (6): 31-33.

[3] Xiang Xianjun, Zhou Rongjing, Wang Yi. Detection of car control electronic measurement technology, [J]. STM32 intelligent system design based on the 2016, 39 (4): 86-89.

[4] Li Shuxia, Yang Juncheng, LIShu-Xia, et al. A path planning algorithm for indoor cleaning robot [J]. application of computer systems, 2014, 23 (): 170-172.

[5] Sun Guozheng. Interior cleaning robot design and path planning algorithm [D]. Huazhong University of Science and Technology, 2015

[6] Zhang Chao. Design of intelligent cleaning robot and its path planning [D]. Harbin Institute of Technology, 2012

[7] Zhongben Tao, Sun Yunfei. Application of storage and handling robot [J]. computer control system based on STM32 2016, 25 (7): 49-54.

[8] Liu Hai-tao, ZHANG Tie.Study on High Precision Robot Control System [J]. Machine Design and Manufacture, 2014 (1): 161-163.

[9] Ma Yan, SONG Ai-guo.Design of Control System of Force Feedback Rehabilitation Robot Based on STM32 [J]. Measurement and Control Technology, 2014, 33 (1): 74-78.

[10] Fan Lu-yi, WANG Dong-qing, LI Fang, et al.Design of palletizing robot control system based on STM32 [J]. Industrial Control Computer, 2014, 27 (11): 69-71.