Research

Quadruped Robot Control System Based on STM32 Single Chip Microcomputer

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Abstract: Although legged robots are commonly used compared with other kind of robots, they are convenient to move any terrain. Specially, when the surface is rough and uneven. Leg robots have advantages over robot with wheel because they are ideal for circumstances of this kind. In order to implement legged robots, many motors normally need to move each joint in leg robot. The construction cost, motion of the robot and its demand for power supply and weight increased by additional motors. This research is focused on design a quadruped robot based on body structure of four legs mammals and mechanism layout can maximize the motion range of robot feet in the horizontal plane. Its control system based on STM32F103VET6, using the timers of STM32F103VET6 to produce 12-channel PWM wave to control robot’s legs. The experiments show that joints motion control of 12 degree-freedom is stable, the smarter and smaller control system can control complex movement gait precisely and the robot can achieve ground motion.

Keywords: Quadruped robot, Stm32F103VET6, Control system.

1. INTRODUCTION

Along with the advance of science and technology and the rapid development of computer technology, the robot technology is more and more gotten attention. All kind of robots such as leg robot, wheel robot and so on are going into our life. Recently, Mobile robots and artificial intelligence era have obtained great achievement. Moreover, enormous research has been conducted by universities, multinational companies and even by the military, to understand the high mobility and stability of autonomous robot on rough terrain. Study on mobile robot is a
hotspot in the field of robotics research. An example of the application using mobile robot is the scanning of buried land mine [1].

Mobile robots are made of two kinds: the robots with wheels and legs [2, 3]. Robots with wheels or legs have their own pros and cons. Wheel robot are more common in use because of their design and construction. In addition, the cost of a building wheel robot is generally low compared with leg robot. However, leg robots are excellent on uneven surfaces and rough terrain. Legged robots are ticker to design and built as compared to the wheeled robot. This is due to the complexity to the actuator and joint. To build a legged robot, the stability factor as well as co-ordination of the movement of the leg bot must be considered [1, 4]. Compared with the wheeled robot, a walking robot foot can cross a long path on the rough surface with a strong environmental adaptability and flexibility, used in engineering exploration survey or military reconnaissance and people can't do or dangerous work. It Still can develop into a home service robot or entertainment robot. Most of today's robots are not very mature, especially the walking stability, complex ground resilience and speed, they are still not very ideal. The research of walking steadily on the complex ground is the key of the robot. The representative achievements of quadruped bionic robot are as follows: in 1967, a quadruped robot prototype designed by McGhee R.B. etc, the University of Southern California, USA, realized stable walking through limited control algorithm [5]. At the same time, the gait matrix is also proposed to study the gait characteristics of the robot [6]. In 1968, Mosher of the General Electric Company developed the first quadruped walking robot with control function at that time, which can realize various functions such as leg lifting, crossing, walking, obstacle avoiding, etc.[7]; In 1986, a quadruped robot was designed by Raibert M.H. of Massachusetts Institute of Technology, which achieves dynamic balance such as buffering and jumping with a retractable leg structure. It can use trot, pace and hound to move forward quickly and stably [8].

By the end of the 20th century, although the major research institutions have made different improvements to the robot, these researches are all focused on the research of the basic design and behavior algorithm of the robot. In 2003, Fukuoka Y et al. of the University of Electro-Communications proposed the control strategy of neural oscillator model, which was a breakthrough in the control research at that time. In this research group, the control strategy of neural oscillator model is applied to the "Tekken" series, dog-shaped robot. On the premise of being equipped with laser and CCD camera, it successfully realizes the fast walking in the closed
corridor when avoiding obstacles, and can identify and avoid the existing targets in front [9]. Among them, Tekken-4 realizes dynamic adaptive walking on the irregular ground.

The outstanding achievements in robot research are as follows: in 2006, a new quadruped bionic robot, Big Dog, developed by Boston Dynamics, was designed by mechanical method. Its power output was implemented by hydraulic drive system. It can jump a 1-meter-wide trench, climb a 35-degree slope, and walk at a speed of 10 km/h, which can meet the speed of infantry element marching on foot. When it weighs 150kg, it can walk adaptively in unstructured relief and keep its motion performance unchanged. These excellent performances of Big Dog became the world leader in the field of quadruped robots at that time [10-13].

The representative achievements of domestic quadruped robots are as follows: QW-1 quadruped omnidirectional walking robot developed by Wang Jinsong et al [14] of Tsinghua University, etc.; JTUWM series quadruped robot [15, 16] developed by Ma Peisum research group of Shanghai Jiao tong University, etc. Among them, JTUWM-III adopts the open-chain leg structure to imitate the walking characteristics of tetrapod. Under the control of DC servo motor, the walking speed of leg joint is about 0.18km/h, which realizes walk in the gait of trot and pace. It can walk stably for more than 10 cycles. PVDF piezoelectric membrane force sensor is set on the sole of the foot, which combines with the fuzzy neural network system to process the force feedback information, so as to improve the motion stability [17].

At present, the research institutions engaged in bionic robot include Beijing University of Aeronautics and Astronautics, Harbin Institute of Technology[18], National Defense of University[19], Shandong University[20], Beijing Institute of Technology[21], Southeast University, University of Science and Technology Beijing and Shenyang Institute of Automation Chinese Academy of Sciences and so on[22]. However, as the quadruped robot is a multi-variable strongly coupled nonlinear dynamic system, the establishment and calculation of its dynamic equation are complicated, as well as high control difficulty by involving many disciplines such as machinery, control and calculation technology. Therefore, the current research on quadruped robot is basically in the laboratory stage. Most of the research content is based on the theoretical simulation and moving gait of robot. There are few robot prototypes, and the degree of intelligence is far from enough. In addition, from the perspective of the development trend of quadruped robot at home and abroad, the robot is becoming more miniaturized, intelligentized, multi-purpose and self-adaptive. Therefore, it is of great significance to develop a small quadruped robot.
experimental prototype to realize stable walking. Based on the above analysis, this study proposes a quadruped robot system and its control strategy based on STM32F103VET6. By analyzing its dynamic modeling, gait and stability, the robot’s stable, swimming and other movements are realized.

Microcontrollers of AVR series [23] and controllers of DSP series [24], are commonly used to control small robot systems in traditional design. With the requirements of the stable ground motion of quadruped robot and its strong adaptability to the surrounding environment, it has highly required for the volume and weight of the control system. At the same time, the posture in the process of motion shall be collected to make corresponding adjustments. And ground impacting force received from the leg-end shall be sensed in real time so as to control it. STM32F103VET6 fully meets the requirements of the motion control system of quadruped robot [25]. Therefore, a quadruped robot control system with its core is designed.

2. METHODOLOGY

2.1 The structure of quadruped robot.

By analyzing the body structure and movement mode of quadruped robot was designed, and its body structure shown in Figure 1. The front and rear legs are symmetrically distributed. Each leg has 3 joints, and each joint is driven by servo. It has 12 joints in total and needs 12 servo motor to realize the movement of the quadruped robot. Each leg has 3 active DOFs. The leg-lifting joint realizes the side swing of the robot. Joint 1 and joint 2 constitute a two-linkage mechanism responsible for driving the body forward. Such motor layout and mechanism layout can maximize the motion range of the robot feet in the horizontal plane.
2.2 Hardware Circuit

The hardware circuit of control system is mainly divided into three major parts, such as main control part, power supply part and communication part [26]. The power supply section is responsible for supplying power to hardware part of the robot control system and the servo motor. The main control part of the robot, responsible for driving the servo motor of the four legs and responding to the control signal of the computer. The communication part adopts serial port communication, which connects USART serial port to RS232 bus driver and receiver MAX3232, and converts TTL level of STM32F103VET6 asynchronous communication port to RS232 level, so as to facilitate communication with computer.

During the driving process of servo, the driving system and control system of the servo motors are powered separately in order to avoid the influence of current fluctuation on the motion stability of the robot. Since the robot uses SG-90 servo motor in order to produce torque, the working current of each servo motor is 200mA. 2.4 A current is needed while 12 servo motor working together. So LM7805 used in the power supply of the servo motor provides 5V voltage for the servo. And the chip allows the maximum output current up to 5 A. The diode bridge rectifier circuit is used at the input end of the power supply to prevent the polarity error when the power supply is connected.
In order to reduce the mutual interference between the power supply of each part of the circuit and the ground, zero ohm resistance is introduced between digital ground and analog ground [27]. Moreover, Control system part of the STM32 needs 2.0~3.6V voltage to power I/O pins and internal voltage regulator, using 1 piece of AMS1117-3 to produce 3.3V stabilized voltage supply. The power circuit of robot servo and power circuit of control system are shown in Figure 2.

![Power Supply Circuit Diagram]

**Fig. 2.** Power supply circuit

The operating frequency of STM32F103VET6 microprocessor can be up to 72MHz, integrates 256 kB Flash and 48 kB SRAM high-speed memory, including three 12-bits ADCs, four universal 16-bit timers, 2 advanced timers and 2 basic timers. There are up to two I2C interfaces, three SPI interfaces, two I2S interfaces, one SDIO interface, five USART interfaces, one USB interface and one CAN interface. All of these fundamentally improve the real time and reliability of the control system. The structure of the main control part is shown in Figure 3.
3. RESULT and DISCUSSION

3.1 Software part of control system.

In the Quadruped Robot control system, PWM signal that is generated from the known gait data is required for each joint steering gear, of which signal cycle is 20ms and pulse width is 0.5 ~ 2.5ms, the corresponding rotation angle range of the steering gear is 0° ~ 180°. The servo motor will remain at the corresponding angle when a control signal is input. The servo motor will rotate to a new angle until the next different signal is received [28-30]. Its working principle is as follow: a reference circuit is set inside the control chip of the servo motor, which can generate a reference number with a period of 20ms and a pulse width of 1.5ms, subtract the external input control signal from the reference signal. The rotation direction of steering gear is determined according to the signal voltage difference, driving the positive and negative rotation of the DC motor in the steering gear. The main shaft of DC motor drives the rotary potentiometer to rotate through the cascade
reduction gear. The voltage signal output from the rotary potentiometer is compared with the target voltage signal converted from the input control signal. When the voltage difference is zero, the motor stops rotating. And the motor remains at the required angle. SM32F103VET6 uses four timers, and adopts PWM output mode. Each timer generates 3 PWM wave. In the software control, the clock, I/O port and Timer are configured first. After the configuration, the joint angle is read according to the command, then the joint angle is converted to the PWM signal required by the steering gear. Finally, PWM pulse width signal with a period of 20ms is output. The control flow is shown in Figure 4.

Fig 4. The control flow of software

3.2. DEBUG AND TESTING

The quadruped robot independently developed and has three active DOFs on one leg, achieving stable forward motion on flat ground. The leg lifting joint was not considered in the experiment, only the motion of Joint 1 and Joint 2 was considered. During the movement of the robot, the angle change curves of Joint 1 and Joint 2 of one leg in one cycle are shown in Figure 5 and Figure 6, respectively.
4. CONCLUSION.

The motion control system of the quadruped robot is designed based on STM32F103VET6 to drive 12 joints in real time, which realizes the stable ground motion. In the process of motion, the whole robot system runs stably and reliably, and the control system controls the robot joints accurately. The control system has good advantages in real-time computing power, storage capacity, peripheral expansibility and miniaturization.
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6. References


Dedication
Not mentioned.

Conflicts of Interest
There are no conflicts to declare.

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