

Motion Control Algorithms for Hydraulically Driven Biped Mobile Robot

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Abstract: Biped mobile robot is a simple mobile robot, which can accomplish some simple tasks, such as the application of explosion removal, and can take the dangerous explosives to the designated place instead of human. Single joint performance of hydraulic robot directly affects the overall control performance of the robot. Uncertainty and time-varying of hydraulic system parameters reduce the accuracy and response speed of single joint control of the robot. Therefore, robustness of single joint controller of the robot is required. The mathematical model of servo valve controlled swing hydraulic cylinder is established, the uncertainty of system parameters is analyzed, and a single joint robust controller is designed by using quantitative feedback theory (QFT). In the automatic mode, the position information of the grasped object is extracted by the ultrasonic distance sensor. The position information of the grasped object is used as the input of the fuzzy control algorithm, and the motion of the mobile robot is driven by the fuzzy control algorithm.

1. Introduction

As an important branch of robotics, biped bionic robots are widely used in geographic exploration, material transportation, emergency and disaster relief because of their flexibility, stability and adaptability to certain environments. Hydraulic drive has the characteristics of high power density ratio, fast response and high output. It has great potential in the application of biped robots with large load capacity. Because of the non-linearity of hydraulic drive system, it is difficult to control the motion of large load. Therefore, aiming at the problems of walking motion control of biped robot driven by hydraulic pressure, simulation and experimental research are carried out in this paper. In this paper, D-H method is used to model the forward and inverse kinematics of biped robot, and the kinematics equation of biped robot is deduced. Combining with the telescopic motion of the hydraulic cylinder, the relationship between the single leg motion variable and the driving variable of the biped robot is established, and the single leg motion space of the biped robot is determined. According to the principle of motion stability of biped robot, referring to the legs space of biped robot, the walking strategy of biped robot is planned. Through the Jacobian matrix of single leg force, the joint forces of biped robot are analyzed and the walking parameters are determined. The simulation model of biped robot is established in ADAMS software, and the designed step strategy is transformed into the driving function of the simulation model, and the design gait is simulated and verified. Using LabVIEW software, the main control program of the whole hydraulic biped robot platform is compiled to realize the real-time control of the hydraulic biped robot. Dead-zone compensation PID control strategy is proposed to solve the problem of overlap in the middle of proportional valve, which improves the position tracking performance of the hydraulic cylinder. The position control of the projection point of the gravity center of the whole biped robot is carried out by the foot force sensor, and the static gait of the biped robot is realized through the whole machine experiment.

2. Hardware Design

According to the double rear drive and independent turning mode of the children's car, it can be seen that the children's car has three motors to drive, so the mobile robot motion control system needs three miniIBTs. Three miniIBTs are all controlled by PWM signals. STM32F103 MCU has four timers, each timer has four channels, each channel can easily generate PWM waves. In this

design, channel 1 and channel 4 are selected as RPWM and LPWM of miniIBT respectively; TIM2 controls turning motor, TIM3 controls left-wheel motor and TIM4 controls right-wheel motor. The EN of three miniIBT is controlled by PD0-PD2 respectively; the D0-D3 of wireless remote controller is connected with PC0-PC3 separately; because it is necessary to judge the relative position of the grabbed object, the relative position of the grabbed object includes distance and direction information. The distance information can be obtained directly from the feedback signal of HC-SR04 ultrasonic ranging module, but the direction information can not be obtained from HC-SR04 alone. So three HC-SR04 are used in the design, which are installed in the middle, left and right of the car head respectively. By comparing the signals returned by three HC-SR04, the direction information can be obtained. For example, if the grab is on the left side of the vehicle sound, the distance information returned by HC-SR04 on the left side is shorter than that returned by HC-SR04 on the middle and right side. The trigger signal of HC-SR04 is triggered by pulse, and the pulse is sent every 60 ms. The echo signal is captured by the input capture function of the timer. The channel 2 of each timer in STM32F103 has the input capture function. Trigger signal is connected with timer channel 3, echo signal is connected with timer channel 2, TIM2-TIM4 corresponds to three HC-SR04 ultrasonic ranging modules, left, middle and right respectively. In motion control system, turning angle and relative displacement should be controlled, so two GK102 transmissive photoelectric sensors are used in the design, one encoding disk is installed on the steering wheel and the other is installed on the wheel for extraction. Turning angle signal and displacement signal. Two output pins of GK102 are connected to PC8 and PC9, PC8 is connected to obtain turning angle, PC9 is connected to obtain relative displacement.

3. Hydraulic Fuzzy Control Algorithms for Hydraulic Robots

Fuzzy control is a rule-based control, which directly adopts language-based control rules. The starting point is the control experience of field operators or the knowledge of relevant experts. There is no need to establish an accurate mathematical model of the controlled object in the design. The motion system of mobile robot is very similar to that of automobile driving system. Driving is a complex problem, which makes it difficult to establish an accurate mathematical model and describe it with mathematical analytic formula. Experienced drivers can drive their cars well, which mainly depends on their experience. According to this idea, using fuzzy control algorithm to solve the motion of mobile robots is a very good solution. According to the design of hardware circuit, the distance signal of HC-SR04 can be used to judge the distance and direction information of the grasping object. The turning angle and relative displacement of the mobile robot are used to control the relative position of the mobile robot and the grasping object. In this design, two independent fuzzy controllers are used to control the turning angle and relative motion displacement. The input is distance and direction information, respectively. In order to realize the simplicity and rapidity, two-dimensional fuzzy controller is adopted in this system, i.e. input E and change rate Ec. The fuzzy controller for controlling turning angle sets the fuzzy subset of language values of input variable direction (E1) and direction change rate (E1c) as {negative large, negative small, zero, positive small, positive large} (negative representing left, positive representing right), and is abbreviated as {NB, NS, Z, PS, PB} and the fuzzy subset of output turning angle (K1) as {NB, NM, NS, Z, PS, PM, PB}; similarly, it controls the relative displacement of motion. The controller sets the fuzzy subset of relative displacement (E2) and relative displacement change rate (E2c) of input variables as {negative large, negative small, zero, positive small, positive large} (negative represents far, positive represents near), and is abbreviated as {NB, NS, Z, PS, PB} and the fuzzy subset of relative displacement (K2) of output motion as {NB, NM, NS, Z, PS, PM, PB}. The domain of membership function of input variable is [-2,2], and that of output variable is [-3,3]. The membership functions are all triangular functions with high sensitivity, uniform distribution and equal distance in the domain.

According to the driving experience, E1, E1c and K1 should satisfy the following rules:

- (1) When $|E1|$ is larger and $|E1c|$ is larger, the larger K1 should be chosen.
- (2) When $|E1|$ is medium, appropriate K1 should be taken.

(3) When $|E1|$ is small and $|E1c|$ is small, the smaller $K1$ should be chosen.

$E2$, $E2c$ and $K2$ should satisfy the following rules:

(1) When $|E2|$ is larger and $|E2c|$ is larger, the larger $K1$ should be taken.

(2) When $|E2|$ is medium, appropriate $K1$ should be taken.

(3) When $|E2|$ is small and $|E1c|$ is small, the smaller $K1$ should be chosen.

Based on the above considerations, E and change rate E_c are used as input of the fuzzy controller. The fuzzy control rules of $K1$ and $K2$ are shown in Tables 1 and 2, respectively.

Table 1 $K1$ Fuzzy Control Rules Table

$E_c \backslash E$	NB	NS	Z	PS	PB
NB	PB	PB	PB	PB	PM
NS	PM	PM	PS	PS	PS
Z	PS	Z	Z	Z	NS
PS	NS	NS	NS	NM	NM
PB	NM	NB	NB	NB	NB

Table 2 $K2$ Fuzzy Control Rules Table

$E_c \backslash E$	NB	NS	Z	PS	PB
NB	PB	PB	PB	PM	PM
NS	PM	PM	PS	PS	PS
Z	PS	Z	Z	Z	NS
PS	NS	NS	NS	NM	NM
PB	NM	NM	NB	NB	NB

4. System Software Design

According to the motion control system of mobile robot, the system software can control the display screen, miniIBT motor driver, RO3BS wireless receiving module, HC-SR04 ultrasonic ranging module and GK102 transmission photoelectric sensor (including initialization, output of control signal and acquisition of return signal etc.) and also include information display, signal processing of sensor and fuzzy control. The completion of some events such as system algorithm. The software design of the system adopts modular design method. The whole system is mainly composed of the main program of the system and various functional subroutines. The main program mainly completes system initialization, interface display (including welcome interface, mode selection interface and mode information interface), switch between modes, remote control signal reception and other functions. The function subroutines mainly include remote control driving, reading remote control signals, acquiring relative position of grabbers, fuzzy control algorithm and automatic driving subroutines.

5. Conclusion

In order to improve the servo accuracy of the actuator of the hydraulic biped robot during its operation, the equivalent model of the electro-hydraulic servo actuator is deduced, the load characteristics of the actuator are analyzed, and the minimum control integrated control strategy of the flow compensator is proposed, and the working principle of the composite control strategy is given. Flow compensator and proportional position inner loop are used to suppress the influence of external disturbance force and inertial load change on system performance, and minimum control integrated controller is used to further correct the deviation, so as to achieve high-precision position

control of the system. The validity of the simulation model is illustrated by the comparison between the joint simulation of MATLAB and AMESim and the semi-physical experimental platform. The simulation experiments of variable inertia load and random disturbance force of electro-hydraulic servo actuator are carried out under the joint simulation environment. The experimental results show that the hydraulic robot controlled by intelligent algorithm performs well in balance and coordination.

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