Design of Mobile Control system for wheeled Mobile Robot based on embedded ARM Technology

Lin Rong-Xia
Huali College Guangdong University of Technology, Guangdong Guangzhou, 511325, China

Abstract. The mobile control of the wheeled mobile robot is affected by local disturbance error, which leads to low control precision. A mobile control model of wheeled mobile robot based on RTK-GPS (real-time kinematic GPS) is proposed. The mobile control system of wheeled mobile robot is designed with embedded ARM technology as the core processor of controller. Firstly, the mobile control algorithm of wheeled mobile robot is designed. The attitude determination parameter of wheeled mobile robot is taken as the control constraint parameter, and the attitude determination control of the wheeled mobile robot and the path map traversal of attitude parameter output are processed. According to the coordinate position of the locus map, the robot’s moving location is carried out, and the trajectory following adjustment is realized by RTK-GPS technology, and the control law is optimized. Then the hardware of the control system is developed under the embedded ARM technology integrated information processing environment. The robot attitude adjusting system, the central integrated control module and the man-machine interaction module are designed and described in detail. The system test results show that the proposed method has better output performance, lower attitude determination error and better control convergence of wheeled mobile robot.

1. INTRODUCTION
With the development of robot technology, a large number of bionic wheeled mobile robots appears in industrial operations, which improve the precision and efficiency of industrial operations. Wheeled mobile robots as an important direction of intelligent robot, it shows good application value in grasping and moving control. Mobile wheeled mobile robot is affected by environment error and steady-state adjustment error of wheeled mobile robot in grasping and attitude determination, which results in low precision and large steady-state error of wheeled mobile robot. It is necessary to optimize the control system of mobile wheeled mobile robot. This paper presents an optimal design scheme of wheeled mobile robot mobile control system based on embedded ARM technology. The design of wheeled mobile robot mobile control system mainly includes two parts: control algorithm design and control system hardware design. First, the overall design description and technical index analysis of the wheeled mobile robot mobile control system are carried out, and then the control algorithm optimization design of the wheeled mobile robot mobile control system is carried out. Finally, the hardware of the control system is designed under the embedded ARM technology environment, and the simulation test of the control performance of the system is carried out. The advantages of the wheeled mobile robot mobile control system designed in this paper in improving the control ability of the wheeled mobile robot are demonstrated.
2. Overall design and technical specifications

2.1 Design principle and overall frame of control system

Aiming to realize the optimal design of mobile control system of wheeled mobile robot, the overall design framework of the system is analyzed. The mobile control system of wheeled mobile robot designed in this paper mainly realizes the mobile attitude determination control and grasp control of the wheeled mobile robot, improves the precision of attitude determination and grasping, and establishes the data analysis model of mobile control of the wheeled mobile robot. Combined with sensor information fusion and data acquisition method, the mobile control constraint parameter data of wheeled mobile robot are collected [4], and the trajectory following adjustment and information fusion processing are carried out according to the collected attitude parameter data of wheeled mobile robot. The data acquisition module of mobile control system of wheeled mobile robot mainly includes three axis accelerometer, attitude sensor, Speed sensors and magnetometers, the control parameters of the wheeled mobile robot are mainly the rotational angular velocity, moving velocity, acceleration and inertia parameters of the wheeled mobile robot. The mobile control object model of wheeled mobile robot is constructed, and the control parameters of trajectory following adjusting output are processed by self-tuning qualitative fusion, and the system is developed and designed under the embedded ARM technology environment [5]. The hardware module of the wheeled mobile robot mobile control system designed in this paper mainly includes the robot attitude adjusting system, the central integrated control module and the man-machine interaction module. The ISA/EISA/Micro Channel extended bus is used to load the instruction of remote automatic control of the wheeled mobile robot mobile control system. The communication module of upper computer is designed for man-machine interaction and integrated data upload. The input module of the control instruction is used to load the control instruction and process the output of the actuator in the mobile control system of the wheeled mobile robot, and the bus data transmission module is designed to transmit the integrated bus data of the mobile control system of the wheeled mobile robot. According to the above general design description, the overall structure block diagram of the mobile control system of wheeled mobile robot designed in this paper is shown in figure 1.

![Figure 1. overall structure of mobile control system for wheeled mobile robot](image)

2.2 System design technical index analysis.

According to the overall structure shown in figure 1, combined with the application environment of wheeled mobile robot mobile control system, the technical specifications of the control system designed in this paper are analyzed. The core of the system design is the choice of signal processing chip. The 21160 processor of ADI's A embedded ARM technology is used as the digital processing chip. The minimum sampling rate of attitude parameter acquisition of wheeled mobile robot is 12 MHz, and the 8-bit A / D chip is used for inertial attitude fusion. According to peripheral device selection and functional module analysis of wheeled mobile robot mobile control system, the technical specifications of the wheeled mobile robot mobile control system designed in this paper are given as follows:

(a) The main frequency of parallel resonance and the maximum output power of wheeled mobile robot are 112MHz and 120kW respectively, which satisfy the mobile control function of high-power wheeled mobile robot.

(b) The output power loss is less than 24kW, and the parallel tuning error of wheeled mobile robot is less than 0.02 rad/s.
(c) The ability of resisting resonance interference is about 3dB, and the output static power loss is 12W.

(d) The control error level of mobile control of the wheeled mobile robot is \(13 < SL < 15\)dB. It has the function of precise positioning and output execution of wheeled mobile robot.

The mobile control system of wheeled mobile robot is designed based on the analysis of the above technical indexes. Before this, the optimal design of control algorithm is needed[6].

3. Control algorithm design

In the design of control algorithm, this paper presents a mobile control model of wheeled mobile robot based on RTK-GPS (real-time kinematic GPS)[7], which makes the distribution set of motion control parameters of wheeled mobile robot \([q_1, \ldots, q_7]^{T}\). The attitude inertial fusion matrix \(i^{-1}T_i(q_i)\) of wheeled mobile robot can be expressed as follows:

\[
\begin{bmatrix}
c_i & -s_i c_a & s_i s_a & a_i c_i \\
s_i & c_i c_a & s_i s_a & a_i s_i \\
0 & s_a & c_a & d_i \\
0 & 0 & 0 & 1 
\end{bmatrix}
\]

(1)

Under the unknown condition of the reference configuration \((\theta_0, \beta_0, \gamma_0)\) of the wheeled mobile robot, the 4 × 4 homogeneous coordinate matrix \(i^{0}T_0(a_0, b_0, c_0)\) is used for information fusion. The output fusion attitude sensing information matrix \(i^{0}T_i(\theta_1, \theta_2, \theta_3)\), combined with the sensor quantization fusion tracking method is applied to the attitude determination compensation control of the wheeled mobile robot. The output linkage equation is described as follows:

\[
\prod_{i=1}^{7}i^{-1}T_i(q_i) = \begin{bmatrix} n & o & a & p \\ 0 & 0 & 0 & 1 \end{bmatrix} \text{ (2)}
\]

According to the disturbance characteristic of wheeled mobile robot, the self-adaptive solution of attitude parameter is carried out, and the integrated qualitative control output of attitude parameter of wheeled mobile robot under Kalman fusion filter control is obtained:

\[
q_1 \equiv \theta_{d1} = \text{atan}2(\pm p_{4y}, \pm p_{4x}) \text{ (3)}
\]

\[
q_2 \equiv \theta_{d2} = \text{atan}2(\mp p_{4z}, c_1 p_{4x} + s_1 p_{4y} \cdot \ell_4) \text{ (4)}
\]

Similarly, get the \(q_3\) and \(q_4\):

\[
q_3 = \text{atan}2(-s_4 o_{4x} + c_4 o_{4y} \cdot s_2 c_4 o_{4z} - s_2 s_4 o_{4z} - c_2 o_{4z}) \text{ (5)}
\]

\[
q_4 \equiv \theta_{d3} = \text{atan}2(c_2 c_4 n_{4x} + c_2 s_4 n_{4y} - s_2 n_{4z}, c_2 c_4 a_{4x} + c_2 s_4 a_{4y} - s_2 a_{4z}) \text{ (6)}
\]

The optimal output control law is obtained by adjusting the attitude error compensation of the wheeled mobile robot under the driver conversion control:

\[
4T_5^{-1}(q_i) \cdot 4T_7 = \prod_{i=0}^{7}i^{-1}T_i(q_i) \text{ (7)}
\]

The IK analytic equations for mobile control of the wheeled mobile robots are expressed as follows:

\[
x(k+1) = \Phi_i(k)x(k) + w_i(k) \quad i = 1, 2, \cdots, m \text{ (8)}
\]

\[
z(k) = H_i(k)x(k) + v_i(k) \quad i = 1, 2, \cdots, m
\]

Combined with terminal position state compensation and parameter adjustment, the optimized output parameters are \(Q(k)\) and \(Q_e(k)\). Based on the above analysis, the mobile control law of wheeled mobile robot is optimized[8].

4. Hardware Design and implementation of control system
The hardware design of the wheeled mobile robot mobile control system is based on embedded ARM technology. The hardware structure of the system consists of the robot attitude adjustment system, the central integrated control module and the human-computer interaction module. The attitude adjustment system of the robot adopts Mux101 multiplex switch to control the terminal position of the mobile robot mobile control system, and the information fusion is carried out in the trajectory following regulator. The AD module is used to collect the integrated information of the wheeled mobile robot mobile control system, and the central control module is introduced into the DAQ-STC to modify the terminal position and pose of the wheeled mobile robot. The embedded ARM is used for the bus drive and control instruction loading of the control system. The central integrated control module is the core of the whole control system design [9]. Floating point embedded ARM technology and fixed-point embedded ARM technology are used to load the single cycle instruction information of the control system. The integrated information processing of the wheeled mobile robot control system is realized in embedded ARM technology. The clock circuit and output interface circuit are designed in the man-machine interaction module, and the clock sampling of the control instruction is carried out. In order to improve the integrated processing ability of output control signals, the asynchronous sampling of control instructions is carried out by using the AP-D chip to control the clock oscillation of the wheeled mobile robot control system by using the driver circuit. The mobile control instructions of the wheeled mobile robot are transmitted to the PC machine via the PCI bus, and the remote communication between the output SPI interface and the host computer is carried out to improve the remote control ability of the mechanical movement. According to the description of the above design scheme [10], the hardware composition of the wheeled mobile robot mobile control system designed in this paper is shown in figure 2.

![System hardware design structure diagram](image)

**Figure 2. System hardware design structure diagram**

5. Test analysis

Aiming to test the performance of the wheeled mobile robot mobile control system designed in this paper, the simulation experiment is carried out. In the experiment, the control algorithm is designed by Matlab, and the hardware test is based on the Simulink simulation platform. Visual embedded ARM technology 4.5 is used to build a joint simulation platform for mobile control of the wheeled mobile robots. In the simulation parameter setting, the piezoelectric control digital of wheeled mobile robot is \( \Delta D = \frac{65536 \times V}{5} \), sensor quantization fusion tracking sampling baud rate is 12 Mbps. The initial state of wheeled mobile robot attitude determination is \( X = [0.12 \quad 0.25 \quad 0.15 \quad 0.45] \), inertial attitude fusion characteristic coefficient is set by \( F_1 = \begin{bmatrix} 0.1 \\ 0.1 \end{bmatrix}, \quad F_2 = 0.1 \), according to the above simulation parameters. The mobile control of the wheeled mobile robot is carried out, and the simulation scene is shown in figure 3.
Input control parameters into the interface of figure 3, test the performance curve of wheeled mobile robot mobile control with different control models. The wheel speed curve is shown in figure 4, and the torque change curve of traction motor is shown in figure 5.

Analysis figures 4 and 5 show that the proposed method has lower error and better convergence, and can realize the convergence of attitude parameters in 1.2 s simulation time. The convergence error of the control state variable is 0.034, which reduces the error rate by 24% compared with the traditional method. This method has higher precision and better control performance for the wheeled mobile robot.

6. Conclusions

The wheeled mobile robot is affected by the environment error and the steady-state adjustment error of the wheeled mobile robot, which results in the low precision of the wheeled mobile robot and the large steady-state error. In order to improve the control performance, an optimal design scheme of wheeled mobile robot mobile control system based on embedded ARM technology is proposed in this paper.
The control algorithm of wheeled mobile robot and the hardware design of the control system are designed. The overall design description and technical index analysis of the wheeled mobile robot mobile control system are carried out. The improved control algorithm is used to optimize the control law of the wheeled mobile robot mobile control system. The hardware design of the control system is carried out under the embedded ARM technology environment, and the simulation test of the control performance of the system is carried out. The research shows that the method in this paper can improve the precision of mobile control of the wheeled mobile robot, with less error and better convergence.

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