Intelligent mobile robot control system based on PC+ underlying motion controller

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Abstract. Open-structure mobile robot motion control system based on “PC + underlying motion controller” could take advantage of the high degree of good versatility, real-time performance, high processing capacity of PC, and high controlling capacity of underlying motion controller. And the overall design of the open-structure mobile robot motion controller based on PC + stm32 is developed, which contains the system control architecture, the layered architecture of the control system and the human-computer interface. An algorithm also proposed for estimating the robot’s position and orientation, and the experimental system built for the prototype, provided the platform for moving, monitoring and automation. Experimental results of the proposed control system show that the open-structure mobile robot owns the stability, accuracy, rapid response and exact localization.

1. Introduction
Mobile robots will become human friendly and convenient assistant in the future, and adaptive to coexist with people harmoniously become necessary [1-2]. Mobile robot control system is put forward more and more high demand, and the traditional closed system for mobile robot control system has gradually become obsolete due to its scalability, flexible. Therefore, people urgently demand that the robot control system should be developed from the traditional closed-end to the open.

Mobile robot technology integrates multidisciplinary field of knowledge, the key technologies can be divided into four parts including path planning, navigation, localization and motion control. Currently, Open-structure mobile robot motion control system based on “PC + underlying motion controller” is widely used due to the high degree of good versatility capacity of PC and high controlling capacity of underlying motion controller. However, the underlying motion controller used in the open-structure mobile robot, shows some problems on versatility, the control architecture of hardware and software that also affects the openness of the mobile robot. Therefore, after learning the structural characteristics of the open robot motion controller, Open-structure mobile robot motion control system based on “PC + stm32” is designed that make the users able to enhance their applications conveniently. Then the open control system is connected to the PC and a set of complete layered system framework set up.

2. Decisional System Framework
Mobile robot is a kind of robot system, which can discern the environment, and its own state by sensor and realize the target autonomous movement in an environment with obstacles, so as to accomplish certain functions. Design and development of an autonomous mobile robot necessitates the integration of several sensors and actuators on a physical base to admit the robot for ability to interact with their environment and achieve their tasks [3]. A system for an autonomous mobile robot need perform
various complex information processing tasks in real-time. Robotics has become a good tool for learning, not only of automation and robotics itself, but of general areas in science, technology and engineering [4]. Paper focuses on the design of control system, and presents an open distributed motion control system as shown in Fig. 1, the open robot motion control system with interoperability, portability, alternative, scalable and can be secondary developmental, has become the mainstream of the robot motion control system development direction [5].

Due to its movement characteristics and work requirements, intelligent mobile robot’s speed and position is required. This paper adopts the form of the three-layer system structure to control the whole system running, the upper computer layer, the behavior information layer and the lower control layer. This paper selects the Elmo SimplIQ servo drive, and selects maxon series motor, the specific model is RE30; The specific parameters are shown in table 1 below:

Table 1. RE30 motor parameters

| Parameter          | Value            |
|--------------------|------------------|
| Rated voltage      | 24V              |
| Locked-rotor torque| 1160mNm          |
| Rated current      | 3.36A            |
| Torque constant    | 292 mNm /V       |
| Rated speed        | 6910rpm          |
| Speed constant     | 328 rpm/V        |
| No-load current    | 168mA            |
| Moment of Inertia  | 78.7gcm²         |
| No-load speed      | 7670rpm          |
| Time constant      | 5.6ms            |
| Starting current   | 39.7A            |
| Maximum Efficiency | 84               |
| Rated torque       | 93.3mNm          |

In order to meet the requirements of the intelligent mobile robot, this paper chooses a layered control structure. The whole structure consists of three layers, which are the upper computer layer, the behavior information layer and the lower computer control layer, as the structure diagram shown in Fig. 2.

3. Control platform design of control system

Hardware control system is of great significance to realize stable operation and accurate feedback of mobile robot. In view of the motion characteristics, to ensure good real-time communication and servo control characteristics, reasonable controller and hardware structure should be selected that the mobile robot can work accurately and efficiently. In this paper, stm32 is selected as the main control chip, which mainly includes power system, communication system, sensor system and signal processing system. The hardware control system mainly includes mobile controller, motor drive system, DC servo
system, I/O module, communication module and human-computer interface. Each module can play its own special function and cooperate with other devices, and jointly complete the tasks of the robot software system. The hardware framework of the control system is shown in (a) and (b) as shown in Fig. 3 below:

![Control system distribution](image)

Fig. 3 Control system distribution

4. Upper computer debugging program
In the practical application of mobile robots, upper computer is MFC procedures. To implement the serial communication with stm32, this paper writes an MFC window interface. Serial port debugging program can select serial port 1 and serial port 2 and this paper selects serial port 1, sets serial port transmission parameters, and automatically sends control commands periodically.

Upper machine and lower machine communication configuration is completed, this paper uses a hierarchical human-computer interface, including the function of human-computer interface module, as shown in Fig. 4, the design of the mobile robot task environment purpose is reasonable to complete a series of tasks, and told the robot to complete the task order, at the same time to the completion status of other modules such as information sharing, the human-computer interface is shown in Fig. 5, mainly including mobile robot control bar; a serial port configuration information display status information, the robot task requirements, such as movement status display information, a serial port configuration and sensor information sub-window interface.

![Task scheduling module function diagram](image)

Fig. 4 Task scheduling module function diagram

![Software system layout window](image)

Fig. 5 software system layout window

5. Mobile robot experiment and conclusion
The data acquisition of this experiment is mainly in the following way: The orthogonal coded signals obtained by the photoelectric encoder are entered into the orthogonal coded pulse peripherals of the control board controller stm32. And the system uses photoelectric encoder in unit time to detect the displacement of the robot's left and right wheel differential signal. This paper will consider a mobile robot system with 4-dc motor drive, namely a mobile robot with four independently actuated wheels. This consider is motivated by the truth that this kind of mobile robot is a common in applications now, and its simple architecture keeps the notation simple. Meanwhile, this proposed methodology could be extended easily to consider more complex kinematic and dynamic models subsequently.
5.1 Confirm the error compensation value
In this paper, X-directional motion is chosen as the error reference, through times of X direction measurement data to calculate the error compensation value as the compensation value system, and the mobile robot is depicted in Fig. 6.

![Fig. 6 the mobile robot](image)

A Gaussian process regression curve for the measured data is obtained through MATLAB. The following curves are shown in Fig. 7 and Fig. 8, and the confidence interval of 0.95 is obtained by observing the X direction data of the mobile robot on the curve, we choose the mean as error compensation values.

![Fig. 7 error compensation curve](image)

![Fig. 8 the samples detail drawing](image)

From the graph, we can see that the error value increases with the increase of displacement. The maximum error in the displacement range of 0~35m is 1.2m. Each time we pass an experiment, a set of mean data get.

5.2 Experimental verification
We arrived at location through many times test for 10 m, Angle of 0 ° posture to validate the above error compensation value. For comparison purposes, the data of the 13 groups were measured: In this experiment, the user was requested to drive the robot to visit a sequence of the same target locations many times, and the running environment is depicted in Fig. 15. The results are summarized in Table 2. R and L represented the cumulative value of differential position signal for left and right wheels; (the actual location of the point at which a value of (10 m, 10 m), Angle 0 °, the value of error compensation, the 0.36 m)

| R    | L    | Measuring position | Actual location | Measuring Angle | Actual Angle | Position error | Angle error |
|------|------|--------------------|-----------------|----------------|--------------|----------------|-------------|
| 10.617 | 9.039 | 9.828              | 10.000          | 0.298          | 0.000        | 0.172          | 0.298       |
| 9.713  | 9.798 | 9.756              | 10.000          | -0.016         | 0.000        | 0.245          | -0.016      |
| 10.132 | 9.577 | 9.855              | 10.000          | 0.105          | 0.000        | 0.146          | 0.105       |
| 10.398 | 9.860 | 10.129             | 10.000          | 0.102          | 0.000        | -0.129         | 0.102       |


| 9.622 | 10.360 | 9.991 | 10.000 | -0.139 | 0.000 | 0.009 | -0.139 |
|-------|--------|-------|--------|--------|-------|-------|--------|
| 12.013 | 11.319 | 11.666 | 10.000 | 0.131 | 0.000 | -1.666 | 0.131 |
| 10.756 | 9.387 | 10.072 | 10.000 | 0.258 | 0.000 | -0.072 | 0.258 |
| 9.539 | 11.013 | 10.276 | 10.000 | -0.278 | 0.000 | -0.276 | -0.278 |
| 8.898 | 10.642 | 9.770 | 10.000 | -0.329 | 0.000 | 0.230 | -0.329 |
| 8.847 | 10.598 | 9.723 | 10.000 | -0.330 | 0.000 | 0.278 | -0.330 |
| 9.486 | 10.820 | 10.153 | 10.000 | -0.252 | 0.000 | -0.153 | -0.252 |
| 9.164 | 11.043 | 10.104 | 10.000 | -0.355 | 0.000 | -0.104 | -0.355 |
| 10.019 | 10.556 | 10.288 | 10.000 | -0.101 | 0.000 | -0.288 | -0.101 |

The results of the orientation error are shown in Fig. 9: except for the sixth group, the remaining measurements are within the margin of error compensation.

![Fig. 9 results of position and orientation error](image)

6. Conclusion
This paper completes the control system architecture design of the open-structure mobile robot motion controller based on PC + stm32, which contains the system control architecture, the layered architecture of the control system and the human-computer interface. This paper also proposes an algorithm for estimating the robot’s position and orientation. Finally, this paper completes the system control experiment and the experiment of the position and orientation error, the experimental results show that the mobile robot owns reliable control system, stable operation, quick response and accurate positioning.

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