Design of an Omnidirectional Mobile Robot Capable of Launching Projectiles

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Abstract: The manufacturing technology of projectiles has become very mature and common in the market, but currently, research on projectile mobile robots is still in the theoretical stage. This article introduces a robot that can move and launch projectiles in all directions. This unique design structure allows the robot to move flexibly in complex environments and launch projectiles when necessary to meet the needs of special tasks. The goal is to design and implement a projectile launch robot with high maneuverability, autonomy, and difficulty. This article analyzes the requirements of the robot control system, points out the hardware architecture and operation process of the omnidirectional mobile robot, and describes the functional implementation of the robot. This article also conducted projectile launch experiments and omnidirectional mobility experiments on the robot. It tests its movement performance under various surfaces and angles, as well as the accuracy of projectile launch. The experimental results show that the average accuracy of the robot projectile launcher is 94%, and the omnidirectional mobile robot can launch projectiles from different angles, achieving free movement in both vertical and horizontal directions. The design of this type of robot provides new possibilities for the widespread application of robotics technology.

Keyword: Mobile Robot, Full Range of Motion, Launcheable Projectile, Freertos Operating System, Chassis Control

1. Introduction

In today's society, the development of robotics technology is increasingly attracting people's attention and attention. Robots play important roles in many fields, such as healthcare, manufacturing, military, and education. However, traditional robots can only move on a fixed plane and cannot achieve all-round movement and flexible control. Therefore, designing an omnidirectional mobile robot that can launch projectiles is of great significance.

The design of omnidirectional mobile robots is currently an important topic in robot technology research. Mina Sadat Ebrahimi uses navigation algorithm to track the track of omnidirectional robot through behavior based control, aiming at a new simulation of mutual orientation of two robots. This method is used to conduct fixed direction simulation, so that the robot kinematics can obtain the equations related to

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wheel speed and torque [1]. Thanh Tung Pham has designed a new sliding mode PID (Propulsion Integral Derivative) controller and Radial basis function neural network omnidirectional mobile robot based on a new quasi sliding mode. In order to reduce the shaking phenomenon around the sliding surface, the tanh (hyperbolic tangent) function was used in the robustness clause of the controller, and it was found that the shaking phenomenon has been reduced [2]. Kaibo Zhang designed an automatic omnidirectional robot that uses a regular camera and adopts different strategies based on different targets to achieve tracking of any target. The feasibility of the system was verified through experiments. The success rate of tracking exceeds 90%, which has high reliability [3]. Omnidirectional mobile robots can freely move in complex environments, not only improving work efficiency, but also replacing manual operations in many fields, reducing labor costs and risks.

With the rapid development of technology, robot technology has been widely applied in various fields. In this context, robot design that combines omnidirectional movement and projectile launch functions is receiving increasing attention. Kaiwen Xue proposed a new mechanism for projectile launch, which involves two key parts: a projectile based launcher mechanism and a bowl shaped magnetic charger socket. The proposed mechanism was evaluated through laboratory pool indoor experiments and lake field experiments, with a success rate of nearly 90% [4]. The above research has achieved good results, but there is too little research on omnidirectional mobile robots that can launch projectiles.

This article proposes a design scheme for an omnidirectional mobile robot that can launch projectiles. The robot changes its position and direction by firing bullets, achieving all-round movement and flexible control. By launching projectiles, the robot can achieve vertical and horizontal movement, while utilizing the projectile impact reaction force to change the robot's direction. By testing the movement and manipulation of robots in different environments, the effectiveness and feasibility of the design scheme have been demonstrated

2. Overall Design of Omnidirectional Mobile Robots

2.1 Requirements for Robot Control System

The control system is the brain of a robot, which is the foundation for processing robot data, motion, and actions. This project puts forward higher requirements for control systems [5-6].

The control system must be robust and reliable. To achieve this, software should be designed to monitor tasks in real-time, remove underlying controllers, and allow communication between high-level tasks. If there is a problem with one task, other tasks can be arranged in a timely manner to minimize losses.

The control system requires precise control of motion. The stability and accuracy of head and frame movements affect the launch control system of the robot. When designing robots, the most important thing is for the head to reach the desired position stably, accurately, and quickly, and for the launch control system to achieve precise motion.

The control system requires an accurate and intelligent sensor system, and the robot must be able to perceive its own motion, posture, speed, position, etc. [7-8]. In order to achieve an intelligent sensor system, a complex, diverse and robust sensor system is required. The control system must extract, process, and intelligently apply data from sensor systems to perform all tasks of the robot.

It can control the intense characteristics of the Real-time Control System [9-10]. Any industrial system must have high real-time performance, processing various sensor data and real-time operations, so it requires hardware such as microcontrollers to interrupt embedded processors. Moreover, as robots have many tasks, they require an operating system that can be programmed in real-time to execute tasks correctly and without conflicts.

2.2 Hardware Architecture of Omnidirectional Mobile Robots

The robot hardware consists of a kernel layer, a peripheral management layer, and a task layer [11-12]. The kernel layer consists of the stm32f4 kernel and the Freertos operating system. The peripheral management layer executes the basic configuration and operations of the MCU (Microcontroller Unit), while the peripheral control layer is responsible for the execution and scheduling of system tasks, which is the foundation for the entire system operation. The peripheral management layer is implemented by control functions and is responsible for controlling peripheral devices. The task layer consists of responsible tasks corresponding to each domain, which are linked together to provide interactive feedback to users and receive gyroscope data from the Robomaster C board to ensure stable rotation of the roll and pitch axes. The launch task controls the launch, ensuring the rapid and stable launch of bullets. Offline detection tasks determine the current state of the device; Servo drive control for user tasks; The user task of the referee system communicates with the referee system, receives and sends data from the referee system, and displays it on the user end; The communication task communicates with the visual system, sending and receiving data from both parties, as shown in Figure 1.

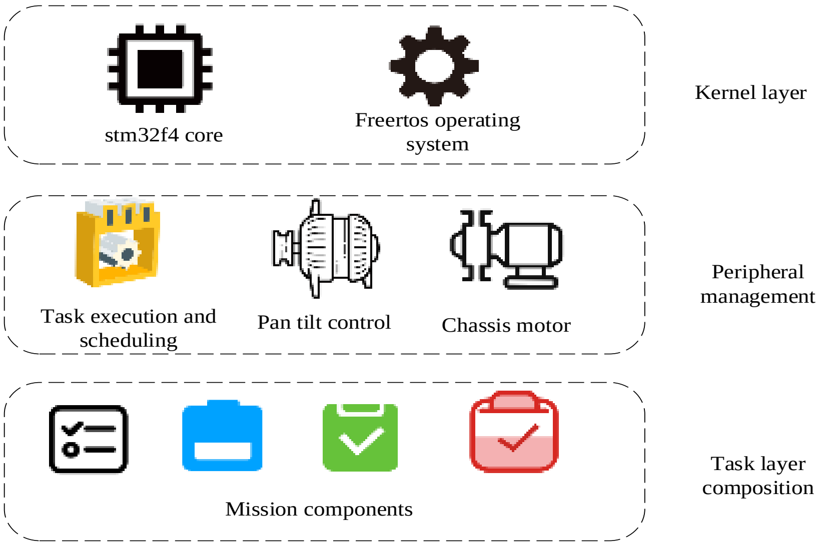

Fig.1 Hardware Architecture of Omnidirectional Mobile Robot

2.3 Robot Operation Process

The entire process starts from low-level initialization, and after all low-level configurations are completed, the Freertos operating system is opened. By continuously receiving and processing data transmitted from the outside and providing corresponding target data, each part of the task is executed in a hierarchical loop.

Freertos arranges the system by repeatedly executing module tasks, updating data during each connection and data transmission process, and publishing new control quantities at the task level. All external hardware transmits the current data back to the main control platform, where Freertos performs appropriate control tasks, and after processing the data, outputs the information to the appropriate destination, as shown in Figure 2.

The chassis motor in the chassis task and the universal joint motor in the pan tilt joint load communicate with the main control platform through CAN1 (Controller Area Network). The blade motor, friction wheel motor, and gyroscope in the launch load communicate with the main control platform through CAN2; The referee system communicates with the Minicomputer through the main control platform. The main control chip directly controls the steering wheel through its internal pins.

Before each task, there is a program that determines the current running mode before updating data. It receives and processes data sent from outside. It should receive the returned data, calculate the data, update the control values, and finally send the control values to the target.

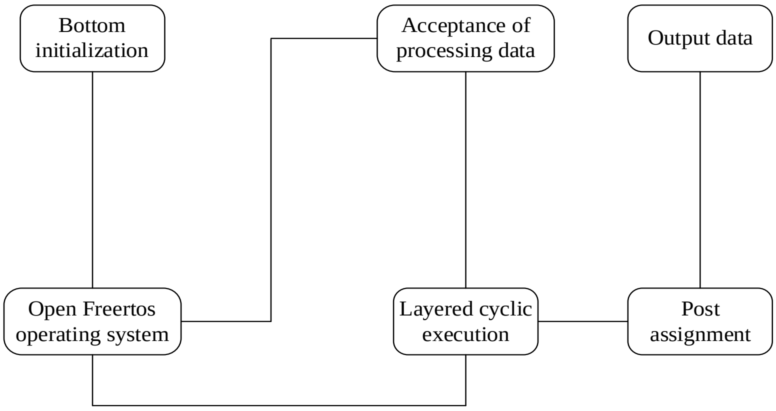

Fig.2 Robot operation process

2.4 Function Implementation of Robots

2.4.1 Robot Chassis Control

Chassis control uses the positive Kinematics of the chassis to move and guide the robot [13-14]. The specific principle is that a rigid body has three degrees of freedom in motion on the plane: forward and backward motion V_x along the x-axis, left and right motion V_y along the y-axis, and rotational motion W_z around the z-axis. The forward direction of the frame is the positive direction of the x-axis, the left direction is the positive direction of the y-axis, the z-axis is perpendicular to the top, and the counterclockwise direction is the positive direction of rotation of the frame. The basic process is as follows: first, initialize the chassis, mainly by setting initial values and initializing PID parameters, and then enter the main cycle. The cycle first updates the chassis data, including the chassis motor speed and the angle of the universal joint encoder (when the chassis follows the universal joint). Then, these data can be processed according to different control modes. If the landing gear is closed, the value of the landing gear motor current is directly set to 0. Otherwise, the required robot speed in the xy direction would be calculated through keyboard or remote blade control [15-16].

2.4.2 Pan Tilt Control

Pan tilt control, including using a remote control and mouse to control the angular velocity and angle of the pan tilt, as well as controlling the angle when self-aiming is enabled. A series PID can be used for continuous control of the universal joint shaft. Two controllers can be controlled in series using a series PID. Series control often controls different physical quantities of the same degree of freedom. For example, the universal joint control of robots uses an angular velocity loop and an angular rotation loop for series control. Angular velocity and angular rotation are both degrees of freedom, and angular velocity is a modulation of angle [17-18]. These two control loops are divided into outer loop control and inner loop control, usually with the angle assigned to the outer loop control and the angular velocity assigned to the inner loop control. The output of the outer ring is connected to the input of the inner ring. The input of the angle loop of the outer loop is the control target, and the output of the angle loop of the outer loop is the specified angular velocity, which is the input of the angular velocity loop of the inner loop.

The basic process of PTZ control is as follows: PTZ is initialized, mainly by setting initial values and initializing PID parameters, and then entering the main loop [19-20]. In this cycle, the seat measurement data is first updated, including angle and angular velocity, and then processed according to different control modes. If controlled by a mouse or remote control paddle, the angular velocity is determined by the control signal and no angle loop calculation is performed. If there is no control data, the previous angle should be retained and PID calculation of the angle loop should be performed on this basis. If automatic steering is identified and enabled, the angle loop PID calculation should be based on the angle calculated from the automatic steering data. The result of the angle loop PID calculation is the expected angular velocity. Then it performs speed loop PID calculation and obtains the expected motor current value based on the expected angular velocity in the above control mode.

2.4.3 Launch Mechanism Control

The control of the launch mechanism includes the control of the speed of the friction wheel and the control of the ejection disc. The speed of the projectile is obtained based on the information provided by the arbitration system, and the speed of the friction wheel is adjusted based on the information provided by the arbitration system. When the magazine is activated, the PID is initialized. Based on the operator's operation, for single pull mode, the position PID is first calculated, or for continuous pull mode, the friction wheel speed is directly determined. Then, the speed PID of the magazine can be adjusted to obtain the required motor current.

3. Experimental Design of an Omnidirectional Mobile Robot Capable of Launching Projectiles

In order to verify the effectiveness and feasibility of a launching projectile omnidirectional mobile robot, experimental tests were conducted. The experiment is divided into two main links, namely the projectile launch experiment and the all-round movement Achievement test.

The projectile launch experiment mainly tests the accuracy of the robot's projectile launch device. The experiment sets targets and observes the effect of the robot aiming, launching, and hitting the target. This article repeats the experiment 4 times, with 100 groups per experiment, and records the accuracy of the projectile launch (the number of times it hits the target). The specific results are shown in Figure 3.

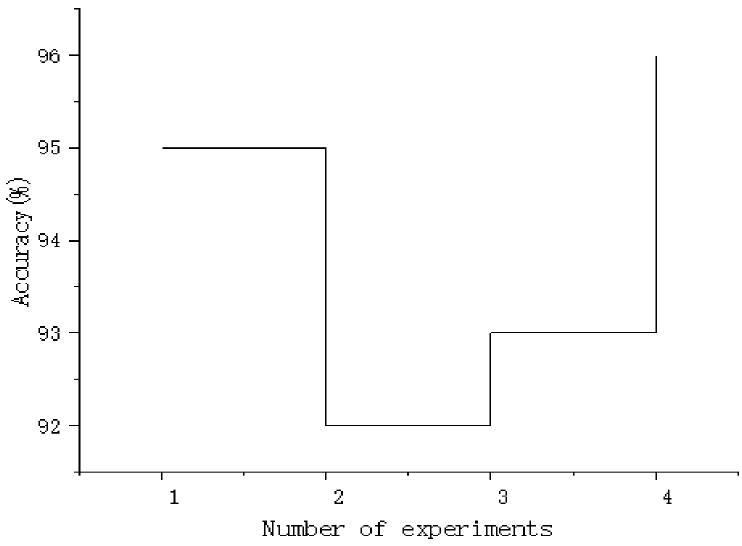

Fig.3 Accuracy testing of projectile launch device

From Figure 3, it can be seen that the accuracy of the experimental test is between 92% and 96%, and it is found that the robot can accurately aim and launch projectiles to hit the set target. The average accuracy of the robot projectile launcher is 94%.

Omni directional mobile Achievement test:

The main purpose of the omnidirectional movement Achievement test is to verify that the robot can move freely in all directions. The target position is set in the test site, with a total of five steps. Then, the robot is allowed to change its position by firing projectiles to observe whether it can effectively reach the set target. To ensure testing accuracy, this article conducts 10 tests. The test results are shown in Table 1.

Table 1. Omni Directional Mobile Achievement Test

	Step 1	Step 2	Step 3	Step 4	Step 5
1	√	√	√	√	√
2	√	√	√	√	√
3	√	√	√	×	√

4	√	√	√	√	√
5	√	√	√	√	√
6	√	×	√	√	√
7	√	×	√	√	√
8	√	√	√	√	√
9	√	√	√	√	√
10	√	√	√	√	√

From Table 1, it can be seen that through multiple rounds of testing, the projectile capable omnidirectional mobile robot can be launched. It can launch projectiles from different angles, which allows for free movement in both vertical and horizontal directions.

4. Conclusions

Traditional robot design is often limited by the design of mobile mechanisms, allowing robots to exert their advantages only under certain environmental conditions and task scenarios. This article endows robots with more active and free mobility through projectile launch, enabling them to effectively move and execute tasks in various complex environments, greatly improving flexibility and adaptability. The omnidirectional mobile robot moves and controls its direction through the reaction force generated by the projectile launch, achieving high flexibility in various scenarios. It solves the shortcomings of traditional robots in terms of mobility and flexibility. The experimental results show that the robot has high projectile launch accuracy and can accurately move according to the set path and target, proving its reliability and effectiveness. This article opens up new possibilities for the development of robotics technology and provides a solid foundation for practical applications in more fields in the future.

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