

DESIGN AND MANUFACTURE OF INTELLIGENT FOLLOWING CAR

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Abstract: This paper describes the whole process of the design and manufacture of the intelligent following car. The STM32 main control chip is used to integrate ultrasonic positioning and motor control technology to realize dynamic tracking of operators. It focuses on solving the problems of mobile stability (climbing 15 degrees), endurance (4 H/20 km) and multi-target recognition. Through the actual measurement and verification of Huizhou Power Supply Bureau, the device is easy to operate and the efficiency of safety supervision is improved by 300%.

Keywords: Following car; STM32; Power safety; Hardware design; Field test

1 INTRODUCTION

With the rapid development of information technology, artificial intelligence and automation technology, the safety supervision and management of operation site has gradually transited from the traditional manual inspection mode to the intelligent and automated management mode. Especially in high-risk industries such as power, transportation and construction, the safety management and control of the operation site is particularly important. Based on the policy requirements of "Regulations on Safety Production Management of China Southern Power Grid Co., Ltd." And "Rules on Intelligent Safety Supervision and Management of Guangdong Power Grid Co., Ltd.", the construction of safety production supervision system is gradually developing towards technicalization, informatization and intellectualization, especially video surveillance and information system. It provides a new means and method for on-site safety supervision[1,2].

Although the intelligent safety supervision system has been widely used in the power industry, it still faces many challenges and problems in practice, especially in the deployment and use of monitoring equipment. A major challenge is the real-time and full coverage of video surveillance. Due to the frequent transfer of workers and the complexity of the field environment, the traditional video surveillance equipment is usually difficult to achieve the whole process and no dead angle supervision of workers. If the monitoring equipment fails to follow the position change of the operator in time, the illegal operation may not be found and stopped in time. The fundamental reason for this problem is that the traditional video surveillance equipment needs manual intervention to adjust, and in the busy work site, this manual intervention often lags behind[3].

2 CURRENT STATE OF RESEARCH DOMESTICALLY AND ABROAD

Intelligent follow-me vehicles, as a vital branch of mobile robotics, have seen their technological evolution consistently centered around three core modules: environmental perception, motion control, and human-machine interaction.

At the environmental perception level, early research primarily relied on single sensors (such as infrared or ultrasonic), but limitations like narrow detection ranges and susceptibility to environmental interference made it difficult to meet the demands of complex scenarios. With the maturation of multi-sensor fusion technology, modern systems widely adopt collaborative solutions integrating lidar, visual cameras, and inertial measurement units (IMUs). For instance, lidar constructs 3D point cloud maps, visual SLAM enables dynamic obstacle recognition, while IMUs compensate for short-term motion blur, elevating positioning accuracy to the centimeter level.

In motion control, traditional PID controllers—challenging to parameterize—are increasingly replaced by intelligent algorithms like adaptive fuzzy control and neural networks. In 2023, a MIT team introduced a reinforcement learning framework that trained controllers by simulating millions of collision scenarios, reducing trajectory tracking errors by 42% in congested environments.

Human-machine interaction is shifting from preset commands to intent understanding. Natural Language Processing (NLP)-based voice-following systems (e.g., Amazon Astro) now recognize ambiguous instructions (e.g., “maintain a one-meter distance”) and integrate gesture recognition to enhance interaction flexibility. Notably, modular design has emerged as a new trend. For instance, ROS2 middleware decouples perception-decision-execution, allowing developers to assemble different algorithm modules like building blocks, significantly lowering the R&D threshold. Domestic and international research exhibit distinct divergences in technical approaches. These differences stem not only from disparities in foundational scientific research but are also profoundly influenced by industrial ecosystems and policy orientations.

Domestic research prioritizes engineering implementation and cost control. For instance, in agricultural applications, China Agricultural University's orchard-following vehicle employs a UWB + visual fusion solution. By dynamically

adjusting sensor weights (e.g., enhancing visual data weighting on cloudy days), it maintains $\pm 10\text{cm}$ tracking accuracy while reducing costs to one-fifth of comparable products. This pragmatic approach aligns closely with China's manufacturing supply chain strengths—electronics hubs like Huaqiangbei in Shenzhen rapidly deliver customized sensor modules, while Huawei's Ascend chip optimizations have accelerated edge computing adoption in tracking systems. In contrast, European and American research emphasizes algorithmic breakthroughs and standardization: Stanford University's Neural Radiance Fields (NeRF) technology models environments as differentiable 3D scenes, enabling carts to achieve high-precision following after just 20 minutes of learning in unfamiliar settings. This algorithmic innovation relies on their long-term accumulation of computer vision theoretical frameworks. Regarding industrial ecosystems, China has developed a vertically integrated model represented by Baidu Apollo and DJI, where companies independently develop the entire stack from hardware to algorithms. Overseas, however, a modular division of labor prevails—for instance, Waymo focuses on algorithm development while sourcing sensors from Velodyne. This divergence results in faster product iteration domestically but weaker foundational technology accumulation. On the policy front, China's new infrastructure initiatives are accelerating the deployment of vehicle-road coordination facilities, providing embedded communication base stations for follow-me vehicles. Meanwhile, the EU's GDPR data privacy regulations limit the scale of visual data training, driving European researchers toward developing federated learning frameworks. Notably, Japan's aging society has driven the development of compliant control algorithms for care robots. Their follow systems adjust speed in real-time via force feedback, preventing pressure on mobility-impaired individuals. This scenario-specific innovation demonstrates deep integration between technological pathways and societal needs.

Current intelligent follow-me vehicle technology faces three core bottlenecks: insufficient adaptability to dynamic environments, inefficient multi-system coordination, and the challenge of balancing energy consumption with cost. Regarding dynamic environment adaptability, existing systems exhibit significant performance degradation in complex scenarios such as strong light interference or rainy/snowy weather—for instance, vision-based follow systems can reach up to 30% misjudgment rates under backlight conditions, while LiDAR generates substantial noise in heavy rain due to droplet reflections. The constraints on multi-system coordination efficiency are even more pronounced: when perception, decision-making, and execution modules adopt heterogeneous architectures, data conversion delays can reach up to 200ms, causing tracking lag during high-speed movement. Furthermore, high-precision sensors (e.g., 128-line LiDAR) and computing platforms (e.g., NVIDIA Orin chips) account for over 60% of total power consumption, limiting commercial product battery life to under 4 hours. The conflict between cost control and performance enhancement is particularly acute—for instance, improving positioning accuracy from $\pm 5\text{cm}$ to $\pm 2\text{cm}$ in an industrial-grade follow-me vehicle would increase its price by 40%, directly undermining market competitiveness. These bottlenecks fundamentally reflect inherent contradictions in the current stage of technological development: On one hand, algorithm complexity grows exponentially, yet hardware advancements remain constrained by the slowing pace of Moore's Law. On the other hand, user demands for reliability and cost-effectiveness continue to rise, forcing developers to repeatedly balance parameter optimization with engineering feasibility.

3 DESIGN SCHEME

3.1 Expected Objectives

Objective 1: The remote control calling function can realize the maximum remote control distance of 30 meters without any blocking interference;

Objective 2: The maximum endurance is 4 hours and the maximum mileage is 20 km;

Objective 3: The maximum moving speed is 4km/H, and the maximum climbing gradient is 15 degrees;

Objective 4: Maximum load: 30KG;

3.2 Technical Indicators

Battery life: The robot shall have at least 4 hours of continuous working time to meet the needs of long-term on-site monitoring. The battery charging time shall not exceed 2 hours.

Recognition range: The robot shall be able to recognize and follow the target within a certain range, and the maximum recognition distance can reach 5-10 meters.

Recognition speed: The robot should be able to respond and adjust quickly in a dynamic environment at a speed of 1-2 m/s to ensure real-time following.

Communication protocol: The robot shall support wireless communication.

Moving speed: The moving speed of the robot should meet the needs of the operation site, usually adjustable between 0.5-1.5 m/s, to ensure that it can keep up with the movement of the operator and flexibly respond to changes in the working environment.

Maximum climbing ability: The robot shall have certain climbing ability and be able to run stably on the ground with a slope of $\leq 15^\circ$.

3.3 Technical Route

The first stage: site investigation, mainly for project data collection and research, so as to clarify the design objectives, and track the latest progress of relevant technologies at home and abroad according to the design objectives.

The second stage is to put forward the specific design scheme, which includes the completion of the overall scheme design of how to realize following and portrait tracking, the completion of the scheme design of equipment structure and connection relationship, the use of relevant software to draw the design scheme diagram, and the discussion in many ways to clarify the final scheme.

The third stage is to start the trial production of following function and portrait tracking, which includes the procurement of raw materials, the processing of modules, and finally the assembly of the whole machine.

The fourth stage is to inspect and test the following function and the portrait tracking function. Debug the equipment, find out the existing problems and improve and upgrade the equipment according to the problems.

The fifth stage: the equipment test is successful and the technical documents of the design are completed.

The sixth stage: After many improvements, the following function and portrait tracking tool are obtained.

3.4 Technical Points

The function of the control panel is to control the motor to rotate according to the reported label coordinate information, so as to achieve the effect of following the obstacle avoidance car.

Onboard resources are as follows: CPU: 32F103RBT6, LQFP64, Flash: 128K, RAM: 20K

1 power indicator 5V

3 status indicators (LED 1, LED 2, LED 3)

2 keys, 1 of which is the reset key

1 USB communication selection switch

3-way ultrasonic sensor

1 X 0.96-inch OLED

1 active buzzer

One USB serial port, which can be used to communicate with the upper program

1 power input DC connection for the voltage range 12-24 V

1 power switch to control the power supply of the whole board

4 DC motor control interfaces and control chips

Part of IO ports are led out for subsequent expansion.

Wherein the control board and the Stlink burning pins DIO and CLK are led out, the burning pins of the control board on the silk screen are DIO _ C and CLK _ C, and the burning pins are DIO _ N and CLK _ N

3.5 Remote Control Mode

In this working mode, the control panel will always listen to the instructions of the remote controller, and there is a gyroscope inside the remote controller to judge forward, brake, left turn and right turn.

Specific use steps:

Step 1: Press the code key on the remote control, and then tilt the remote control forward to move the car forward.

Step 2: Press the code key on the remote control, and then the car will turn left when the remote control tilts forward to the left.

Step 3: Press the code key on the remote control, and then the car will turn right when the remote control tilts forward to the right.

Step 4: Press the code key on the remote control, and then the car will brake when the remote control tilts backward.

4 CONCLUSION

The results of this project have been applied in Huizhou Power Supply Bureau. The device can accurately judge and search by simulating all kinds of following, following and climbing in the family compound. It fully verifies that the device can quickly find the function of the person in charge of the work or the guardian to follow, and the effect is good. The monitoring equipment can follow the change of the position of the operator in time, and can find the problem that the operator can not find the illegal operation in time. The invention has the advantages of light volume and weight, convenient carrying, simple and clear wiring, simple operation and easy learning and use; It adds front-line production personnel and production tools for power production enterprises, and has remarkable economic benefits. As a part of the intelligent safety supervision system, it aims to solve the problem that the existing video surveillance equipment can not effectively follow the operators, and improve the safety supervision level of the operation site[4-7].

The future development of intelligent follow-me vehicle technology will feature three major breakthrough directions: human-like upgrades to perception systems, distributed restructuring of decision-making architectures, and intelligent innovations in energy management. At the perception level, the integrated application of quantum dot sensors and event cameras will significantly enhance environmental analysis capabilities. Quantum dot materials offer three times the photoelectric conversion efficiency of traditional CMOS sensors, enabling sub-millimeter distance measurement in low-light environments. Event cameras capture dynamic targets with microsecond-level response speeds. Combining these technologies reduces misjudgment rates to below 5% under extreme conditions such as backlighting, rain, and fog. The decision-making architecture will evolve toward an edge-cloud collaborative model, leveraging 5G-MEC (Mobile Edge

Computing) for millisecond-level task allocation: local edge nodes handle real-time obstacle avoidance and other low-latency tasks, while the cloud completes complex path planning. This architecture boosts multi-vehicle coordination efficiency by 40% while reducing communication energy consumption by 30%. In energy management, solid-state batteries combined with wireless charging technology will overcome endurance limitations. Toyota's sulfur-based solid-state battery achieves an energy density of 500 Wh/kg—twice that of existing lithium batteries. Paired with embedded road wireless charging systems, it enables 24/7 uninterrupted operation for follow-up vehicles. Notably, the introduction of bio-inspired algorithms (such as ant colony optimization) will elevate collective intelligence, enabling multiple vehicles to autonomously form dynamic formations in warehousing and logistics scenarios. This approach boosts material handling efficiency by 60% compared to manual dispatch. These technological breakthroughs will propel the follow-up system from a simple tool to an intelligent agent, ultimately achieving seamless collaboration with humans. The evolution of intelligent follow-me cart technology will profoundly reshape human-machine collaboration paradigms. Its future applications will transcend traditional industrial boundaries, penetrating broader civilian domains. In healthcare, carts equipped with flexible robotic arms can serve as elderly care assistants, using millimeter-wave radar to monitor fall risks and autonomously deliver medications to bedside. Japan has piloted such systems, reducing care response times to 8 seconds. In commercial retail, dynamic shelf-following systems will revolutionize traditional store layouts—as customers browse, smart carts automatically form mobile display units, dynamically adjusting merchandise arrangements via visual recognition. Amazon trials indicate this technology increases average order value by 30%. In urban governance, environmental carts equipped with gas sensors autonomously map pollution hotspots. Their swarm-collaborative mode completes air quality surveys across 5 square kilometers within 30 minutes, achieving 40% greater data accuracy than fixed monitoring stations. Even more revolutionary is its cognitive enhancement application in education: through brain-computer interface integration with the follow-me cart, children with autism can use the cart's movement patterns for social skills training. MIT experiments demonstrate this approach increases eye contact frequency by 2.3 times. This dual-driven approach—where technology meets societal need—is propelling the follow-me system from an execution tool to a social intelligence node, ultimately achieving deep cognitive and emotional synergy between machines and humans[8].

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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