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Design of Intelligent Embedded System for Automotive Mechanical Automation Based on Particle Swarm Optimization

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With the continuous development of China's economy and society, the automobile has become an indispensable means of transportation in people's daily lives, and the improvement of industrial automation has also revitalized China's automobile industry. With the rapid development of automotive technology, embedded technology has also begun to be widely used in the research of vehicle intelligent driving technology. This technology not only significantly reduces the number of driving accidents, but it can also greatly improve the operational efficiency of vehicles. In this work, an intelligent embedded system for the optimization of automotive mechanical automation was designed based on the particle swarm optimization algorithm. This paper introduces the concept and characteristics of intelligent embedded systems for automotive mechanical automation, and explains the advantages of particle swarm optimization algorithm in optimization problems. Moreover, the optimization problems in the design of intelligent embedded systems for automotive mechanical automation are analyzed This paper provides a detailed introduction to the principle and implementation steps of particle swarm optimization, and explores the selection and adjustment methods of algorithm parameters. The experimental results showed that the lateral control error of the vehicle using the system when traveling in a straight line was less than 0.3m, and the longitudinal control error of the vehicle was less than 0.5m/s, which met the system design requirements. The results indicate that the design of an intelligent embedded system for automotive mechanical automation based on particle swarm optimization algorithm is relatively successful, and can effectively improve the performance and efficiency of the system.

Keywords: Particle Swarm Algorithm; Machinery Automation Intelligent; Embedded System; System Design

1. INTRODUCTION

Mechanical automation is an area of technology that integrates multiple fields and has broad application prospects. Generally speaking, it is a form of system engineering. It consists of a program unit, an action unit, a sensing unit, a formulation unit, a formulation unit, and a control unit. In the current economic market, the demand and requirements for mechanical automation technology are becoming increasingly greater. In order to meet developmental and social needs, mechanical automation technology must comprise intelligence and informatization. Automotive mechanical automation can improve production efficiency, reduce manufacturing costs, improve production quality and stability, enhance production safety, and achieve flexible production. Mechanical automation technology plays a key role in the development of intelligent driving of automobiles. It can improve the efficiency and quality of automotive production, improve driving experience and safety, and promote the transformation and upgrading of

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the automotive industry. Therefore, further research on mechanical automation technology is needed to promote the development of mechanical automation technology and intelligent driving of automobiles.

An intelligent embedded system is a computer system that combines embedded technology, software engineering, and artificial intelligence. It is widely used in fields related to humans' daily activities, economic development, and social security. It can also be successfully applied in the field of assisted driving vehicles. The success of driverless vehicles in the future will depend on intelligent embedded technology for their development and application, and these tasks require senior research and development personnel who are experts in intelligent embedded system design technology. Intelligent embedded systems can achieve intelligent driving, interconnection, safety and reliability of automobiles, and promote the transformation and upgrading of the automotive industry.

2. RELATED WORK

With the development of social technology, autonomous vehicles will become a necessity in the future, and mechanical automation technology plays a vital role in the development of auto driving. Krzywdzinski's (2021) analysis of current technological changes suggested that it is natural to live in an era of rapidly increasing automation [1]. Greenlee et al. (2018) believed that although autonomous vehicles are relatively new, the essence of human-computer interaction has the classic characteristics of alert tasks. Drivers must remain focused all the time when driving so as to detect and respond to unexpected and unpredictable events. Road hazards that may not be detected by automation may occur. To the extent that autonomous vehicle drivers need to remain vigilant, performance errors and related safety risks may occur as a function of task time. Vigilance should be a key safety issue in the development of vehicle automation [2]. Wang Xinlong (2022) identified the need to control automation processes at all stages of product manufacturing, which leads to improved production efficiency, economic activity, and product quality, as well as the manufacture and introduction of new products. On the basis of Russian experience, the key stages of implementing automatic control systems for technological processes were pointed out, and the efficiency of activities was improved by introducing the automation of technological process control systems [3]. These researchers believe that automotive mechanical automation is an inevitable future trend, although there are still many safety issues to address in the development of automotive automation.

Compared with general intelligent systems, intelligent embedded systems are systems on chip based on embedded technology. Such systems are small fast, capable of accurate decision-making, and have multiple peripherals. Intelligent embedded systems can be applied effectively to the design of automotive automation. Liu et al. (2020) found that the proposed algorithm can achieve satisfactory detection speed and accuracy on an embedded hardware configuration platform, verifying the effectiveness of the improved scheme [4]. He et al. (2020) studied the application of embedded dynamic intelligent algorithms in computer software testing. The dynamic matrix control algorithm was introduced into the predictive control algorithm [5]. Lee et al. (2018) proposed a robust real-time visual lane detection algorithm with efficient regions of interest, which provided accurate results and met the real-time operational requirements of low computing power embedded systems [6]. These researchers believe that embedded systems can effectively solve various problems in automotive intelligent driving systems.

With the gradual maturity and promotion of intelligent systems, many security risks have been greatly reduced. Liu (2020) used the proliferation of computing technology and the widespread deployment of communication mechanisms to promote the development of autonomous driving, where automated vehicle decision-making and control is achieved by using data obtained by multiple sensors. He introduced the most advanced autonomous driving computing system, including seven performance indicators and nine key technologies, followed by the 12 challenges of achieving autonomous driving [7]. Wang J et al. (2018) believed that network and communication technology can greatly make up for the lack of sensors, and promote information interaction more reliably, more feasible and more effectively, so as to improve the perception and planning ability of autonomous vehicle and achieve better vehicle control. He also introduced the new trends in communication technology in autonomous driving, discussed the current mainstream verification methods, and emphasized the challenges and openness of network and communication in autonomous driving [8]. Huang (2019) proposed a sensor fusion solution that integrated camera video, consumer grade motion sensors, and three-dimensional semantic maps to achieve robust self-positioning and semantic segmentation for autonomous driving. It has been shown that, in fact, sensor fusion and joint learning of multiple tasks can help to achieve more robust and accurate systems [9]. Ren (2019) believed that with the rapid development of artificial intelligence and significant progress in Internet of Things technology, people have witnessed the steady development of autonomous driving in recent years [10]. These researchers believe that the safety of current autonomous driving is a cause for serious concern.

In order to ensure the safety of self-driving vehicles, the autonomous driving technology still needs further development and improvement. For example, the detection and validation of sensors, control systems, and software should be strengthened to ensure their stable operation. Hence, new technologies such as artificial intelligence are being considered as a means of improving the autonomous decision-making and adaptive ability of the auto drive system under complex road conditions.

3. APPLICATION OF EMBEDDED SYSTEMS IN THE AUTOMOTIVE FIELD

3.1 Overview of Embedded Systems

(1) Application of embedded system in automobile mechanical automation

Utilizing the high predictability of embedded automotive systems, language theory is used to establish a set of attack signatures derived from the behavioral model of automotive calculators to detect malicious message sequences transmitted through internal networks [11]. In an autonomous vehicle, the system can be decomposed into several sensor subsystems for: perception, mapping, positioning, motion planning and control [12–13]. The reliability of automotive embedded systems is integrated with the flexibility and capacity of distributed Linux and robotic operating systems based on personal computer (PC) computing systems [14–15]. Modern cars are comprised of many complex embedded and networked systems; hence, the demand for processing and communication resources has steadily increased [16].

(2) The concept of embedded systems

Embedded systems are based on computer science and technology, and focus on applications. Their software and hardware can be freely customized to meet their special needs. This system can control, monitor, and manage other devices. In general, embedded systems have strong comprehensiveness and compatibility. They can integrate corresponding application software and hardware, and have many advantages such as small software code, high degree of automation, and fast response speed. They are also especially suitable for systems with high requirements for real-time and multitasking. Embedded systems consist of supporting hardware, processors, application software systems, and operating systems, all of which can work independently.

(3) Characteristics of embedded systems

With the development of modern intelligent devices, the scale of software systems, the number of modules, the complexity of functions, and the extension of their lifespan have made software maintenance more difficult and costly, especially in embedded systems. Unlike Android- and iOS (iPhone Opening System)-based applications such as the Internet, the implementation of embedded software requires specific hardware. The differences between various types of hardware are evident in the central processing unit (CPU) architecture instruction set, buses and peripherals, power management, printed circuit board circuit design, and other features. In addition, on some interfaces, such as Universal Serial Bus (USB) and Peripheral Component Interconnect Express (PCIe), there may be some compatibility issues, such as multiple and complex interfaces.

(4) Application of embedded system in intelligent driving

Intelligent driving is a cognitive engineering method that utilizes human attention attraction and interference, involving multiple factors such as autonomous driving, network navigation, and human intervention. It requires that the vehicle meet the requirements of the corresponding driving dynamics. By means of sensors in the vehicle, it is possible to obtain relevant visual and auditory signals and information. Based on this, the corresponding slave system is controlled through cognitive computing. Intelligent driving technology includes artificial intelligence, drunk driving automatic parking, fatigue driving status prompt, and other functions. Autonomous driving includes many driving behaviors such as maintaining the lane, overtaking, merging the lanes, stopping at red lights, driving at green lights, and interacting with lights and whistles. The human intervention involves adjusting and responding to the actual road conditions when the vehicle is driving. Embedded systems have a wide range of applications in intelligent driving, which can achieve functions such as perception, control, communication, and human-machine interaction, promoting the development of intelligent driving technology.

(5) Development of an embedded system

Generally, embedded systems are designed to execute specific functions. Therefore, the first step is to conduct a requirements analysis. After analyzing the functions to be performed by the system, the next step is to design the functional flow and related algorithms. In this system, the constructed security scheme is analyzed and set. After the designing stage, the hardware can be customized. According to the characteristics of the processor interface, it is necessary to select the appropriate hardware, prepare the relevant drivers and interfaces for it, and complete the construction of the hardware platform. Finally, it is necessary to write the software and debug the system hardware and software.

System function analysis:

Because the development of embedded systems is a process of tailoring and editing the software and hardware of microprocessors and systems for specific purposes, requirements analysis is a crucial step in embedded systems, which needs to be very precise. All subsequent hardware planning, system tailoring, and software development are centered on meeting requirements. That is to say, after meeting core functions, the goal is to improve response speed, reduce costs, and include additional functions. Therefore, if there are errors in the requirements analysis of basic functions, subsequent development and maintenance cannot be carried out at all. It is the most basic and crucial step required to determine the development process and software and hardware planning based on the core functions. The functions of the automotive mechanical automation embedded system include sensor data-acquisition, control system processing, data storage and processing, human-machine interaction, fault diagnosis and early warning, as well as remote monitoring and maintenance functions. Together, these functions achieve the automation and intelligence of automotive machinery.

System function segmentation:

After analyzing the requirements, firstly, it is necessary to identify the required hardware modules from the perspective of functional requirements, prepare for their subsequent driver writing and interface implementation, and reduce hardware costs as much as possible while ensuring functionality. Content that can be implemented in both software and hardware, such as key debouncing, should be implemented as much as possible in software to serve the economic goal of controlling cost and volume as much as possible while meeting reliability requirements. When performing functional design and segmentation, it is necessary to apply the principles of practicality, reliability, maintainability, economy, scalability, generalization, systematization, standardization, and modularity.

Hardware design and related design:

Starting with the initial functional analysis, it is necessary to specify the hardware peripherals to be used, and determine the relevant models and control words to prepare for the next stage of driver writing. The writing of drivers requires packaging the name of the device, control words, and the like, and storing them in the operating system as files to facilitate

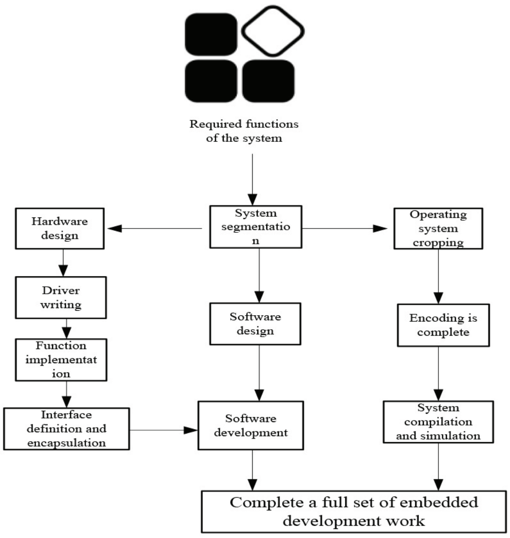

Figure 1 Complete embedded development process

system calls. At the same time, it also allows the writing of applications to access the packaged files instead of directly accessing and calling the hardware, which is convenient for management and facilitates development. Therefore, driver writing and interface packaging are the subsequent steps in hardware design. Together with the system, they occupy a very important position in embedded development, which is also the difference between embedded and traditional single-chip microcontrollers. The hardware design of intelligent embedded systems for automotive mechanical automation needs to consider various factors comprehensively, such as performance requirements, stability, reliability, practicality, etc., in order to achieve automated control and optimization of the automotive production process.

System tailoring and migration:

An intelligent embedded system application software for automotive mechanical automation is an important component of the entire system. Its design involves the selection and use of multiple programming languages and development tools, aiming to achieve automatic control and optimization of the automotive production process. Powerful microprocessors such as Advanced Reduced Infrastructure Set Computer Machines (ARM) and Digital Signal Processor (DSP) still maintain a single threaded working mode without being embedded in the system, which is a great waste of their powerful computing power. Therefore, the important role of embedded systems is to include multiprocessing and multithreading in the system, so that multiple tasks can be scheduled at a macro level, thereby maximizing the utilization of microprocessors. Detailed tailoring of the system, such as the tailoring of its own drives, saves maximum memory space, which is equivalent to saving hardware memory while meeting economic requirements.

Preparation of application software:

After the system has been tailored, a cross compiling environment can be built on a PC computer to simulate the system so that it can be programmed and tested.

In most cases, the development of embedded systems is often based on specific functional requirements. Therefore, the first thing to do is to analyze the requirements of the entire system. After completing the main functions of the entire system, in this current study, the workflow and corresponding algorithms of the entire system are examined. Then a detailed analysis and setup of the constructed security mechanism is conducted prior to proceeding with the design of specific hardware. Appropriate hardware is selected according to the characteristics of the processor interface, and the relevant drivers and interfaces are prepared for it. A hardware platform is built. Finally, the software is prepared and the joint debugging of system hardware and software is done, as shown in Figure 1.

(6) Challenges that automation technology must overcome

Although autonomous driving technology can bring many potential economic and social benefits, there are several limitations and challenges that must be overcome to ensure its safe and effective use. The network security and data privacy protection of self-driving cars must be strengthened to ensure the stability and reliability of vehicle systems. Also, the sensor technology and intelligent algorithm of vehicles must be improved in order to achieve more accurate and efficient environmental perception and decision-making ability. Furthermore, the identification technology and database of road signs and traffic rules must be improved to enhance the intelligent driving level of vehicles. The voice and image recognition technology of vehicles needs to be strengthened and the intelligent service level of vehicles must be improved. Lastly, but equally important, it is essential to consider the liability, insurance and legal ramifications of self-driving cars to ensure the legitimacy and fairness of vehicles.

3.2 Particle Swarm Optimization (PSO) Algorithm

Particle Swarm Optimization (PSO) is an optimization algorithm inspired by the bird feeding model. A particle in the algorithm represents a bird in a flock, and provides a potential solution to each optimization problem. Each particle has a suitable value that matches the objective function. The particle “moves” according to its own motion speed. Each time it “moves”, the particle follows the best particle, searching for it until it finds it. Bento (2021) proposed a method based on hybrid particle swarm optimization to design a wide-area damping controller to ensure robustness to power system operational uncertainties, time delay changes on the wide-area damping controller channel, and permanent failures in the communication channel [17].

(1) Research status of particle swarm optimization application

PSO has a wide range of applications. It was first used to solve the optimization problem of nonlinear continuous functions and the training problem of neural networks, and has achieved good results. For example, a neural network based on the PSO algorithm was used to study the phenomenon of human limb tremors, and a preliminary diagnosis of normal human tremors and Parkinson’s disease was conducted. This method has high computational efficiency and high accuracy. At the same time, it has been successfully applied in power systems. PSO can also be applied to solve general multi-variable optimization problems. It has important applications in dynamics, multi-objective optimization, and other fields. In addition, PSO algorithms can be applied to biological information recognition, decision scheduling, fuzzy control, automatic object detection, workshop scheduling, time-frequency analysis, image segmentation, and other aspects. The PSO algorithm can play an important role in automotive mechanical automation by searching for optimal solutions, achieving functions such as parameter optimization, path planning, fault diagnosis, control strategy optimization, and motion control, improving the performance and efficiency of automotive mechanical automation.

(2) Convergence analysis and parameter selection of particle swarm optimization

Regarding the PSO algorithm, no detailed theoretical research has been conducted on its convergence characteristics; hence, the selection of its parameters depends mainly on experience. However, in practical applications, convergence speed and parameter selection are important factors that determine the performance and efficiency of this method, and there is a close relationship between the two. Several researchers have discussed the convergence properties of this method from a mathematical perspective. Using the basic principle of PSO, the convergence properties of particle swarm optimization are analyzed.

Because the variables of each dimension in PSO are independent of each other, they can be decomposed into one-dimensional variables. To simplify the calculation, if $\omega = c0$, and $c0$, $c1$, and $c2$ are constants, therefore:

$$v(k+1) = c_0 v(k) + c_1 p_b - x(k) + c_2 g_b - x(k) \quad (1)$$

$$x(k+1) = x(k) + v(k+1) \quad (2)$$

From Formulas (1) and (2), the results can be obtained:

$$\begin{aligned} v(k+2) = c_0 v(k+1) + c_1[p_b x(k+1)] \\ + c_2[g_b - x(k+1)] \end{aligned} \quad (3)$$

$$X(k+2) = x(k+1) + v(k+2) \quad (4)$$

Substituting Formulas (3) and (2) into Formula (4) yields the following: $x(k+2) = x(k+1) + v(k+2) = (c_0 - c_1 - c_2 + 1)x(k+1) - c_0 x(k) + c_1 p_b + c_2 g_b$.

That is to say, it is:

$$x(k+2) + (-c_0 + c_1 + c_2 - 1)x(k+1) + c_0 x(k) = c_1 p_b + c_2 g_b \quad (5)$$

This is a class of second-order nonhomogeneous difference systems with constants, and the commonly used solution method is the intrinsic solution.

The first step is to solve the characteristic formula of Formula (5): $\lambda 2 + (-c_0 + c_1 + c_2 - 1)\lambda + c_0 = 0$. According to the discussion of the solution of a quadratic formula of one variable, $\Delta = (-c_0 + c_1 + c_2 - 1)2 - 4c_0$.

(1) When $\Delta = 0$, $\lambda = \lambda 1 = \lambda 2 = (c_0 - c_1 - c_2 + 1)/2$. At this time, $x(k) = (A0 + A1k)\lambda k$. $A0$ and $A1$ are undetermined coefficients, determined by $v(0)$ and $x(0)$. After calculation, this is obtained:

$$\begin{cases} A_0 = x(0) \\ A_1 = \frac{(1-c_1-c_2)x(0)+c_0 v(0)+c_1 p_b+c_2 g_b}{\lambda} - x(0) \end{cases} \quad (6)$$

(2) When $\Delta > 0$, $\lambda_{1,2} = \frac{c_0-c_1-c_2+1\pm\sqrt{\Delta}}{2}$. At this time, $x(k) = A0 + A1\lambda_1^k + A2\lambda_2^k$. $A0$, $A1$, $A2$ are undetermined coefficients. If $b_1 = x(0) - A_0$, $b_2 = (1-c)x(0) + c_0 v(0) + c_1 p_b + c_2 g_b - A_0$. After calculation, this is obtained:

$$\begin{cases} A_0 = \frac{c_1 p_b + c_2 g_b}{c} \\ A_1 = \frac{\lambda_2 b_1 - b_2}{\lambda_2 - \lambda_1} \\ A_2 = \frac{b_2 - \lambda_1 b_1}{\lambda_2 - \lambda_1} \end{cases} \quad (7)$$

where $c = c1 + c2$.

(3) When $\Delta < 0$, $\lambda_{1,2} = \frac{c_0-c_1-c_2+1\pm i\sqrt{-\Delta}}{2}$. At this point, $x(k) = A0 + A1\lambda_1^k + A2\lambda_2^k$. $A0$, $A1$, and $A2$ are undetermined coefficients, and the result can also be obtained with:

$$\begin{cases} A_0 = \frac{c_1 p_b + c_2 g_b}{c} \\ A_1 = \frac{\lambda_2 b_1 - b_2}{\lambda_2 \lambda_1} \\ A_2 = \frac{b_2 - \lambda_1 b_1}{\lambda_2 - \lambda_1} \end{cases} \quad (8)$$

When $k \to \infty$, $x(k)$ has an asymptotic solution that tends to infinitesimal, indicating its iterative convergence. Therefore, when $x(k)$ converges in the above three cases, the following conditions are satisfied: $//\lambda 1// < 1$ and $//\lambda 2// < 1$.

After calculation, the following result is obtained: $c = c1 + c2$.

(1) When $\Delta = 0$, the convergence region is $c_0^2 + c2 - 2c0c - 2c0 - 2c + 1 = 0 (0 \le c0 \le 1)$.

(2) When $\Delta > 0$, the convergence region is the region surrounded by $c_0^2 + c2 - 2c0c - 2c0 - 2c + 1 > 0 (c > 0)$, and $2c0 - c + 2 > 0$.

(3) When $\Delta < 0$, the convergence region is the region enclosed by $c_0^2 + c2 - 2c0c - 2c0 - 2c + 1 < 0$ and $c0 < 1$.

(4) The PSO algorithm model is simplified to a one-dimensional particle case for mathematical calculation.

$$r = \frac{c_1}{c_1 + c_2} p_b c^k + \frac{c_2}{c_1 + c_2} g_b c^k \quad (9)$$

In this way, the formula for correcting the rate can be simplified to $v^{k+1} = c_0 v^k + c(r - x^k)$. Similarly, based on the relationship between $c0$ and c, the convergence zone conditions of the algorithm for these two parameters are obtained.

The PSO algorithm plays an important role in automotive mechanical automation as it can optimize production processes and system design, and improve production efficiency and quality. This can reduce production costs, achieve flexible production, improve system robustness and stability, and further promote the intelligent and automated development of the automotive industry.

4. AUTOMOBILE CONTROL ACCURACY EXPERIMENT

Automated control reduces the impact of human factors on the accuracy of automotive control. For example, automotive mechanical automation systems can automatically control the steering wheel, accelerator, and brakes of a car, thereby improving control accuracy. Automotive automation and intelligence technology is the result of the combination of the electronic industry and the automotive industry. It can effectively improve the dynamic performance of vehicles, enabling users to be safer while driving, and increasing user trust in the vehicle. Among them, the power transmission electronic control system comprising sensors and electronic control units can ensure the stable operation of the vehicle, maintain the vehicle in a normal working state, and prevent accidents. On the other hand, it can facilitate the user's manipulation of the vehicle, making the overall operation more convenient.

4.1 Steering Model and Experiment

(1) Adjustment of mechanical parameters

In order to give the vehicle handling model good dynamic characteristics, it is necessary to adjust the chassis parameters of the vehicle handling model before testing it. In order to ensure the smoothness of the vehicle during straight travel, and achieve automatic steering, and flexible and lightweight steering, it is necessary to make reasonable choices for caster angle, front wheel camber angle, and front wheel toe angle.

a) Caster angle

The caster angle is the angle between the rear of the vehicle and the ground perpendicular. When the carcass is likely to tilt, a restoring moment can be generated to stop it from tilting. The greater the caster angle, the faster the driving speed. The greater the return torque, the better the stability of the front wheels. However, if the reaction force is too large, it would produce a rapid reaction force on the front wheels, causing them to shake, making the steering wheel heavier.

b) Kingpin inclination angle

The kingpin inclination angle is the sharp protrusion formed by the axis of the vehicle steering rod and the vehicle steering rod on a plane orthogonal to the longitudinal axis symmetry plane of the vehicle body. Under the action of external forces, when the model undergoes deformation, the upper half of the model would rise to a certain extent due to the axial inward inclination. After the action of external forces is completed, the tire recovers its original state under the action of its own weight.

c) Front camber

Front wheel camber refers to when the front wheel is installed; its top end is outward so that there is an angle between the rotating surface of the front wheel and the vertical surface of the longitudinal axis. Its main function is to make the steering wheel lighter, allowing the wheels to cling to the inside of the wheel hub. This can reduce the load on the external bearings and wheel nuts, thereby better ensuring driving safety.

d) Front wheel toe-in

Front wheel toe-in refers to the difference in distance between the front and rear sides of the front wheels on the side of the vehicle. Wheel toe-in is used to alleviate or eliminate the adverse effects caused by front wheel camber. The two functions can cooperate with each other to ensure that the front wheels can roll without skidding when the vehicle is running.

The steering model is a commonly used mathematical model that can simulate the steering process and driving trajectory of a car, and plays an important role in the design and optimization of intelligent embedded systems for automotive mechanical automation. It can achieve automated control and optimization of automobiles, improve their performance and safety, reduce development costs and time, reduce actual testing time and cost, and improve the efficiency and quality of the automobile.

(2) Calibration experiment testing extent of control and front wheel rotation angle

In order to provide an appropriate controller for the system, in this current work, the impact of changes in front wheel angle on pulse width was determined via experiments, and results were recorded. The relationship between front wheel rotation angle and extent of control is shown in Figure 2.

As shown in Figure 2, the larger the front wheel angle, the greater is the pulse.

The relationship between the rotation angle and the control amount can be obtained through the above experiments, as shown in Table 1.

Table 1 shows that the pulse width of the angle is steadily increasing from left to right. When the angle is $-36°$, the minimum pulse width is 1180/us, and when the angle is $33°$, the pulse width is 1790/us.

4.2 System Joint Commissioning and Actual Vehicle Testing

In order to ensure the reliability of the test results, in the simulation experiment, repeated tests and random tests should be conducted. Using an experimental simulation testing platform, the testing steps for controller performance in this current study included controller minimum system testing, controller module function testing, Global Positioning System (GPS) reception and analysis testing, Controller Area Network (CAN) communication testing, actuator response

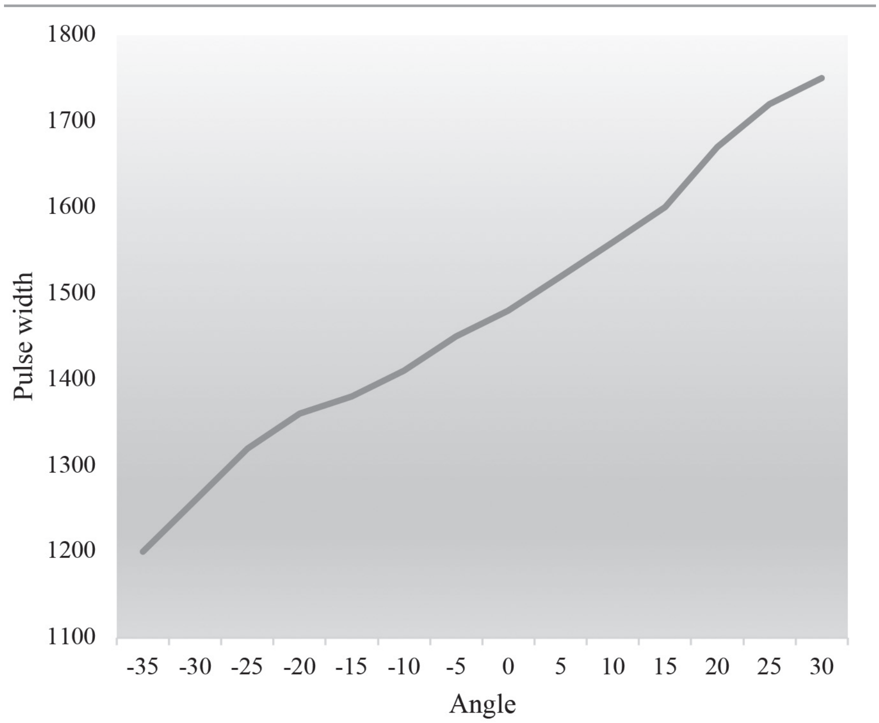

Figure 2 Relationship between control quantity and front wheel angle

Table 1 Relationship between corner and control quantity (negative to the left and positive to the right)

angle	−36°	−28°	−21°	−16°	−7°
Pulse width/us	1180	1250	1300	1360	1430
angle	0°	7°	15°	19°	33°
Pulse width/us	1480	1550	1600	1660	1790

Table 2 Performance index comparison

indicator \ contrast	Expected performance indicators	Test performance	Autopilot performance
GPS Communication rate	115000b/s	115000b/s	——
CAN Communication rate	1000Kb/s	1000Kb/s	——
Steering wheel rotation range	−/ + 500°	−/ + 500°	−/ + 450°
Steering wheel rotation time	<1s	0.77s	<1s
Pedal response time	<1s	0.81s	<1s
Control real-time	<100ms	<100ms	<100ms

time testing, and overall process testing, as shown in Table 2:

As can be seen from Table 2, the system designed in this current study was superior to 100ms, with a response time of less than 1s, reaching the expected performance indicators and meeting the performance requirements of experiments and applications.

(1) System vehicle test

In order to demonstrate the stability and reliability of the system, the proposed system was applied to an actual vehicle for testing, and the effectiveness and accuracy of recorded actual data were analyzed to verify the system's performance. The control of a vehicle in running state was lateral and longitudinal.

In order to ensure that the actual vehicle test has relatively independent characteristics, in this test, instead of using sensing devices such as cameras and lidars to generate a real-time path, on-board positioning equipment is used to collect a set of trajectory data in advance, including the information about the location and speed of the vehicle's running trajectory points. The upper computer program loads the trajectory data, and then sends the predetermined travel trajectory data to the autopilot control system through the bus. The control system tracks the position and speed of the received trajectory in combination with its own position, speed, and other states, and outputs lateral and longitudinal control parameters, thereby completing automatic driving of the vehicle on a predetermined trajectory path.

(2) Lateral vehicle driving test experiment

The lateral vehicle test was conducted on both straight and curved roads. In the straight track test, 80 km/h, 50 km/h, 35 km/h, and 15 km/h were set to detect the accuracy of the vehicle on the straight line. During curve testing, vehicles

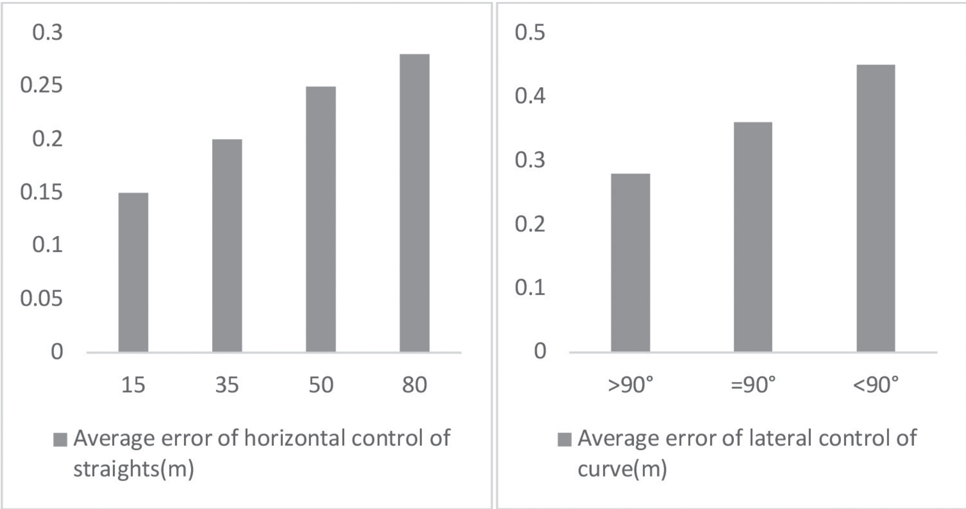

Figure 3 Lateral vehicle control accuracy

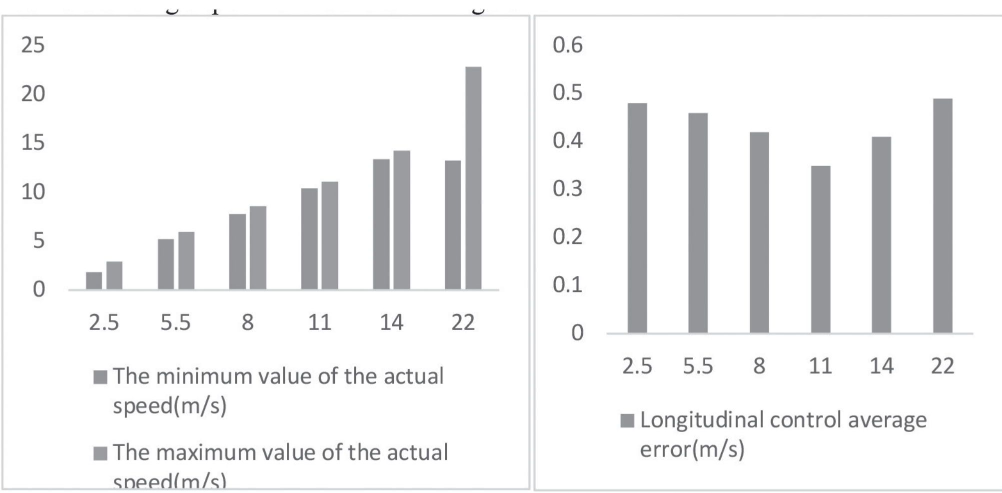

Figure 4 Longitudinal vehicle control accuracy

under different curve conditions were tested based on a speed of less than 20km/h. Transverse vehicle driving is shown in Figure 3.

As can be seen from Figure 3, under different rotational speed conditions, when operating in a straight line, the error was within 0.3 meters. The test results showed that the reproducibility of the test results was good and the conditions for automatic driving were met.

(3) Longitudinal vehicle driving test

The longitudinal vehicle test was conducted on a straight road of 500 meters, and the actual speeds at the set speeds of 2.5m/s, 5.5m/s, 8m/s, 11m/s, 14m/s, and 22m/s were tested under the same experimental road conditions. The comparison with actual test results demonstrated that the algorithm proposed in this paper was effective. The longitudinal vehicle driving experiment is shown in Figure 4.

As can be seen from Figure 4, at different set driving speeds, the average longitudinal control error was all within 0.5m/s, which can also meet the conditions for automatic driving.

The system was tested in an actual vehicle for more than three months, achieving an average speed of 50 kilometers per hour, and achieving automatic driving on predetermined routes. The testing route was about 2000 kilometers. The test results showed that the average lateral control error of the vehicle traveling in a straight line was less than 0.3m, and the average longitudinal control error of the vehicle was less than 0.5m/s. This proved that the system had good stability.

4.3 Application Prospect of Automatic Intelligent Technology in Auto Driving

With the development of China's economy, science and technology, automation technology has made great progress in all walks of life. In particular, there has been significant development in the manufacturing sector, which has played a significant role in improving social productivity and achieving the free development of human beings. Of course, the role of automatic control technology goes beyond these. It can and should provide users with a better experience and more comfort. Therefore, there are still many areas to be developed in the design of unmanned systems. Unmanned driving would completely liberate humans from the task of driving, and research and development in this area still cannot be separated from the application of unmanned driving technology. Nowadays, many companies, including Tesla and Bayerische Motoren Werke, are manufacturing and selling driverless vehicles. However, at present, the relevant technology in this area is not yet mature, and there have been multiple accidents related to it, signaling the need for further improvements. Due to its extremely broad market and bright future, many automotive companies would still invest a lot of manpower and material resources in this area. With further development of automation technology, autonomous driving will gradually enter daily life, thereby changing the mode of transportation and generating great economic benefits.

The research, development and application of autonomous vehicle technology by companies such as Tesla and BMW has huge potential for improving traffic safety and traffic efficiency, which will generate economic and social benefits. Self-driving cars are equipped with advanced sensors and control systems that can respond to the surrounding environment faster and more accurately, thus reducing the occurrence of traffic accidents. According to statistics, the number of people who die from traffic accidents worldwide exceeds 1 million every year, and the popularity of self-driving cars can effectively reduce this number. The technology also enables real-time communication between vehicles, prevents congestion and traffic accidents, thereby improving traffic efficiency. According to the U.S. Department of Transportation, the popularity of self-driving cars can reduce the time delay due to traffic congestion by more than 40%, which has the potential to significantly benefit urban economic development.

Automatic and intelligent technology is developing within the automotive industry, but there are still many shortcomings. Although intelligent technology has fully emerged in many respects, overall, it has not reached an acceptable level of maturity. Given today's social and economic environment, the development of automotive engineering and the widespread application of automation and intelligence technology can, to some extent, meet the needs of a developing human society. From a long-term perspective, the application range of automated intelligent technology in automobiles will gradually expand. Therefore, it is necessary to correctly view automated intelligent technology and give full play to its advantages, so as to comprehensively improve the quality of automobiles.

5. CONCLUSIONS

Firstly, this study analyzed the current problems associated with automotive mechanical automation and intelligence. The embedded system of particle swarm optimization algorithm was used to conduct steering model experiments and determine the accuracy of vehicle control when the system is applied to actual vehicles. Furthermore, an intelligent embedded system for automotive mechanical automation was designed. The aim of the study was to improve the efficiency and quality of automobile production, reduce production costs, achieve flexible production, and improve system robustness and stability. In order to promote the future research and development of autonomous driving technology, it is necessary to strengthen technical research and development, standardization and standardization, data management and privacy protection, legal and ethical research, and industrial coordination. It is necessary to strengthen international cooperation to jointly promote the development and application of autonomous driving technology and bring more potential benefits to economic and social development. However, due to limited professional ability and efforts, there are still many shortcomings in the research and implementation of intelligent embedded systems for the automotive automation explored in this study. The developed system is still far from perfect, and numerous system functions need to be added so as to improve the accuracy of the system for vehicle control. Due to the development of technology, cars can also introduce the concept of "cloud computing" to improve the design of mechanical automation intelligent systems.

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DATA AVAILABILITY STATEMENT

No data were used to support this study.

CONFLICTS OF INTEREST

These are no potential competing interests in this work, and all authors have seen the manuscript and approved it for submission to your journal. We confirm that the content of the manuscript has not been published or submitted for publication elsewhere.

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