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Retraction

Retracted: Hardware Loop Simulation of Distributed Embedded Integrated Circuits

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] B. Wang and Y. He, "Hardware Loop Simulation of Distributed Embedded Integrated Circuits," *Journal of Control Science and Engineering*, vol. 2022, Article ID 4824247, 7 pages, 2022.

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Research Article

Hardware Loop Simulation of Distributed Embedded Integrated Circuits

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In order to improve the performance of the automotive active safety system, the author proposes a distributed embedded ACCS hardware loop simulation system. The automotive adaptive cruise control system (ACCS) is a completely distributed embedded control system. The author adopts the method of hardware loop simulation, an ARM-based automotive ACCS simulation platform is designed, and the hardware structure and software design of the platform are introduced. The simulation results show that the performance of single-node and double-node responses to step change is basically the same. There is a network in the two-node control loop, the carrying capacity and communication bandwidth of the network are limited, which will inevitably cause information collision and retransmission, which will inevitably cause a delay in the information transmission process, with a delay of about 4.5 seconds. The system opens up the design idea of ACCS and also lays a foundation for future research in related directions, which has a certain enlightenment effect.

1. Introduction

Computer technology is beginning to enter an era known as post-PC technology. In today's increasingly information-based society, computers and networks have fully penetrated into every corner of daily life. For everyone, what is needed is no longer just a computer "machine" that sits on a desk to process documents, work management, and production control; a variety of new embedded system devices have far surpassed general-purpose computers in the number of applications, any ordinary person may have a variety of electronic products using embedded technology from large to small, it ranges from miniature digital products such as MP3 and PDA to network appliances, smart appliances, vehicle electronic equipment, etc [1]. In the field of industry and service, digital machine tools, intelligent tools, industrial robots, and service robots using embedded technology will gradually change the traditional way of industry and service.

At present, embedded system technology has become one of the most popular technologies. But, for what is an embedded system, what kind of technology can be called embedded technology is still under discussion. It can be considered that any dedicated software and hardware systems with microprocessors can be called an embedded system [2]. The microprocessor as the core of the system includes three categories: microcontroller (MCU), digital signal processor (DSP), Embedded Microprocessor (MPU). So someone simply said: "Embedded system refers to the integration of operating system and functional software into computer hardware system." Some people think that an embedded system is a special computer system that is "application-centric, based on computer technology, and can be tailored to software and hardware to meet the strict requirements of the application system on function, reliability, cost, size, and power consumption" [3]. It should be said that the latter gives a better definition of the embedded system from the function and application characteristics, and the concept analysis of embedded should basically be cut from the application.

2. Literature Review

At present, many automobile companies and parts manufacturers in the world are committed to improving the safety performance of automobile driving, especially to improve the active safety performance of automobile driving, which has become an important aspect of the development of automobile electronics. Hu et al. proposed the concept of BusySequence to analyze end-to-end messages [4]. The gateway needs to transmit messages from different buses and forward them to other buses, the transmission of messages in the gateway will inevitably cause end-to-end message delays, for this end, Youssef et al. proposed the round search for upper bound (RSUB) method to analyze the WCRT of the gateway task for the first time. In the field of parallel and distributed computing, distributed functions are generally represented by a directed acyclic graph (DAG). The nodes in a DAG represent tasks, and edges connecting tasks represent messages. Multiple tasks and messages with priority constraints compose an end-to-end distributed function. Several related types of research have also been carried out based on the DAG functional model in automotive embedded systems [5]. Devesh et al. from the design point of view of a fusion computing system and network system, based on the DAG function model, an algorithm for end-to-end WCRT optimization of automotive embedded functions based on FlexRay static segment communication is proposed through optimal allocation of time slots. The primary goal of solving the synchronization problem for automotive embedded systems is to propose a synchronization model that can adapt to the system [6]. Liu et al. abstracted the end-to-end computing process into a data flow graph, and set the model as directed, thereby constructing a DAG model; and then based on this model, research is done on the end-to-end synchronous real-time scheduling of automotive embedded systems based on CAN bus [7]. Based on the DAG model, Sivakumar et al. studied the synchronization scheduling optimization problem of time-triggered FlexRay static segments [8]. Chu et al. proposed a DAG model based on a weighted directed graph, studying the end-to-end longest path and worst response time problem of switched ethernet [9].

Automotive ACCS is an intelligent automatic control system, which is mainly composed of a radar sensor, wheel speed sensor, engine controller, and torque controller [10]. Radar sensors can detect the distance in front of the car, and wheel speed sensors are installed on the front and rear hubs to measure the speed of the vehicle. The engine controller and the torque controller are used to detect and adjust the connection and output torque of the engine, so as to improve the power performance of the engine and adjust the running speed of the vehicle in time. Various controllers and sensors are controlled by the in-vehicle computer. A smart car equipped with an adaptive cruise control system adopts active safety technology, the system continuously collects information on the car, the road, and the surrounding environment through various sensors, and adjusts the running state of the car through a computer. It can accurately judge the safety situation around the car, automatically take measures to avoid danger, or choose a safe driving route and working state. The author discusses the construction of the vehicle distributed cruise control system platform and describes the overall situation of the platform and the functions of each part. At the same time, taking the driving environment of the car as the background, the real-time simulation of the platform from simple node system to complex node system is realized.

3. Research Methods

3.1. The Basic Idea of ACCS Design. Most of the simulations of the automotive ACCS system are realized by using the pure software method through Matlab simulation, the hardware loop simulation platform (Hardware in the Loop, HIL) proposed by the author is in the environment of the embedded system, and simulates the environment of the real car; in this way, it is closer to the objective situation of the real car and improves the authenticity and reliability of the experimental environment [11]. Figure 1 is the hardware logic diagram of the automotive ACCS hardware loop simulation platform, the PC simulation terminal, and the embedded system exchange information through the necessary I/O interfaces, such as digital signals, analog signals, and serial ports.

In addition, the following aspects should be paid attention to in the design of the platform:

(1) The simulation system cannot completely replace the physical system of the original car. Therefore, there should be an enabling control signal to start or stop the ACCS system.

(2) During the normal operation of the ACCS system, the driver has the right to change the current running speed of the vehicle.

(3) For the acceleration control and braking control modules, the switch control can be set without using ACCS, and the driver can exercise the control right [12].

The controller of the system adopts a closed-loop feedback control system, firstly, the estimated output value is input to the controller, then the controller generates a control signal and sends it to the controlled system, and the controlled system generates the actual output speed value, and at the same time, the output speed value is returned to the controller, and the controller compares the actual output value with the estimated output value to adjust the errors between them and effectively control the actual output value through algorithm control. Its specific algorithm can be used fuzzy PID control algorithm [13].

3.2. Hardware Design of HIL Platform of Automotive ACCS System. Except for the PC, the hardware part of automobile ACCS mainly uses 10 pieces of the EasyARM2100, and the bus protocol uses a CAN bus structure. It consists of a CAN bus transceiver, JTAG interface, 4 parallel ports, an A/D converter, and corresponding connecting lines. The hardware logic structure is shown in Figure 2.

Each node is connected to the CAN bus through its own interface. The output module relative to each node is the digital output to the parallel port, and the input module relative to each node is the analog input of the sensor. In Figure 2, the five nodes above CANBUS are the main control

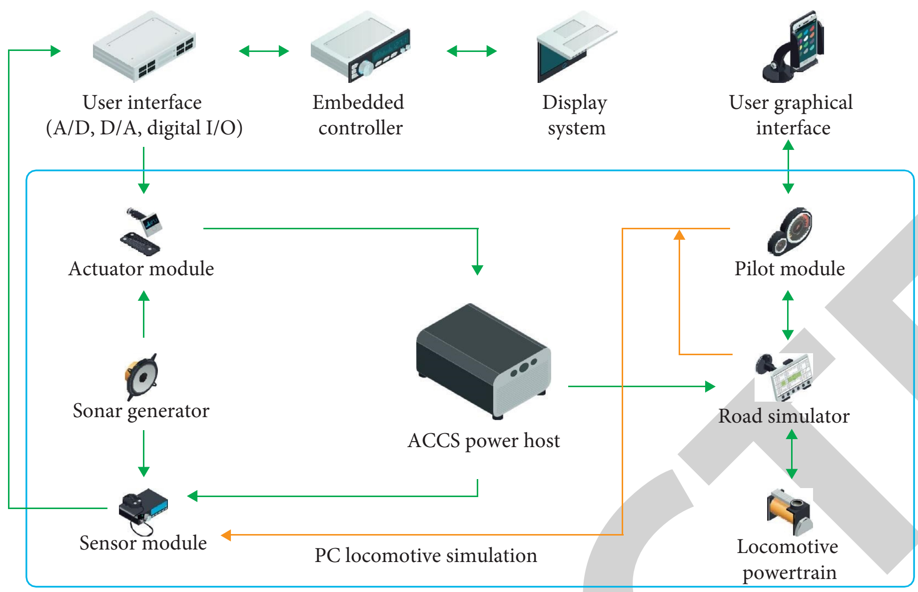

Figure 1: HIL platform hardware logic of automotive ACCS (high-end).

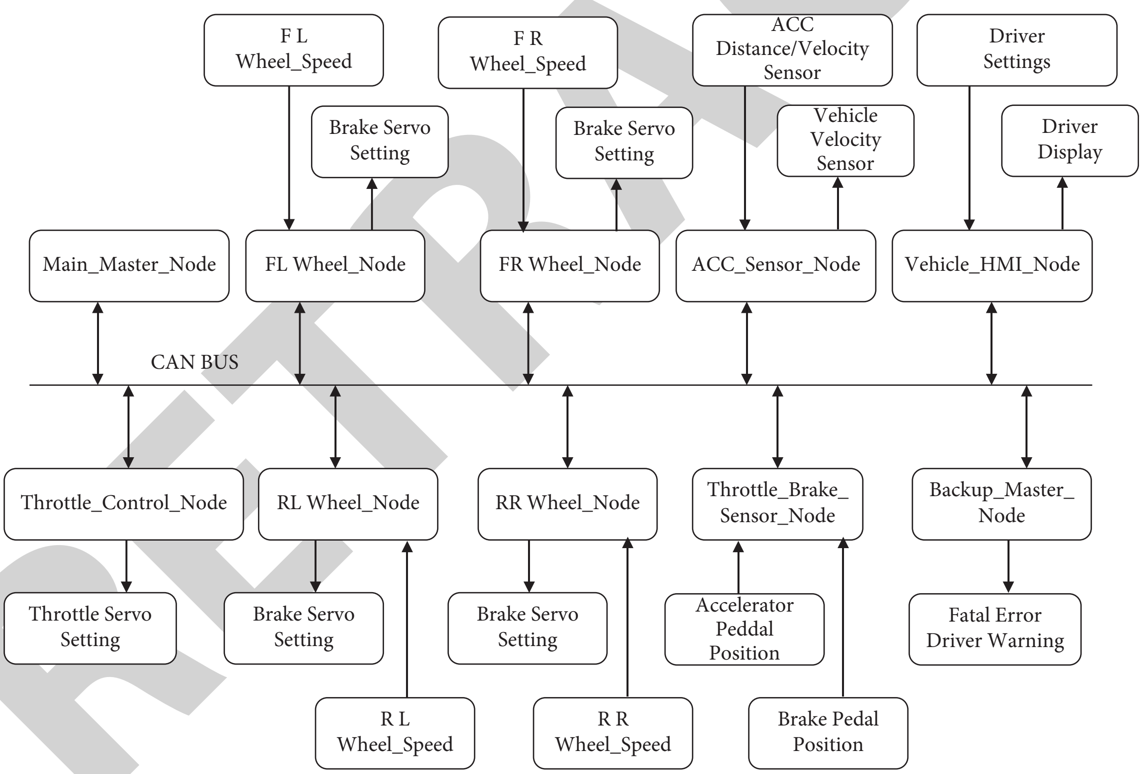

Figure 2: Hardware logic of ACCS.

node, the left front wheel node, the right front wheel node, the ACCS sensor node, and the man-machine interface node. Below CANBUS are the throttle control node, left rear wheel node, right rear wheel node, throttle brake node, and system backup node. The main control node receives the information of each sensor node, and then sends it to each execution node through the network after control operation. The throttle opening control node receives the control amount sent back from the master node, and returns it to the virtual actuator on the PC side through the parallel port; The functions of the 4 wheel (front, rear, left, and right) nodes are basically the same, they receive the 4 wheel speed information returned by the PC, transmit them to the main control node through the network, and then receive the brake information of the main control node and return it to the PC. Each wheel inputs its own speed value into its own node from its own sensor, and at the same time, outputs its own digital quantity to the parallel port; the radar interface node (sensor node) acts as a special sensor node to receive signals such as the distance, relative speed, and body speed of the preceding vehicle; The human-machine interface is mainly to set input and display output, receive driver control information, such as CCS speed information, etc, and display vehicle speed and other information, similar to the vehicle electronic instrument panel. The throttle brake sensor node is used for acceleration control and braking control; The standby node reports whether there is a fatal error and starts the standby master node, which is a warm-up standby node for the master node [14].

The automotive ACCS based on the hardware loop simulation platform is implemented through the four parallel ports (LPT) and a digital-to-analog conversion controller (DAC), making the information between each node interact with the PC.

(1) LPT1 mainly includes 10 bit digital input of throttle valve, CCSRunning input, CCSError input, CCSWarning input, CruiseEnable output, Speed + 5 and −5 output, and CruiseDisable output. The CruiseEnable signal is the enable control used by the PC simulation, whereas CruiseDisable is used to disable ACCS, Speed + 5 and −5 outputs are used to adjust the speed, each adjustment value is 5 units, CCSRunning is the running status flag, and CCSWarning is a non-fatal error flag, the CCSError is a fatal error flag [15].

(2) LPT2 mainly has 8 bit left front wheel digital input and 8 bit right front wheel digital input.

(3) LPT3 mainly has 8 bit left rear wheel digital input and 8 bit right rear wheel digital input.

(4) LPT4 is the main preset setting and analog interface pin, that is connected to the A/D converter chip. There are RST, CLK, SDI, LDA, LDB, CS1, CS2, CS3, CS4, and CS5. where RST is used as reset, SDI, and CLK enable bits to trigger shift register, at the same time, LDA or LDB performs corresponding D/A conversion when CS of the chip is set to a low level, LDA and LDB are activated. The system uses a total of 9 sensor signals (analog) to fully reflect the running state of the vehicle model, namely the left rear wheel speed (RearLeftWheelSpeed), the right rear wheel speed (RearRightWheelSpeed), the right front wheel speed (FrontRightWheelSpeed), the left front wheel speed (FrontLeftWheelSpeed), driver throttle opening setting (DriverThrottleSetting), driver brake setting (DriverBrakeSetting), ACC front vehicle relative speed (ACCTargetDistance), linear vehicle speed (LinearVehicleSpeed), and car setting (DriverSetting) as shown in Table 1.

(5) The 9-channel analog quantity is the digital signal output by the PC, which is the output after a special D/A conversion board. Due to the different signal types, a DAC is required for conversion, to complete the normal communication between the embedded system and the PC [16]. The basic idea is to change some pins of parallel port 4 to serial input pins, clock pins and some chip select signal pins, the wiring of the digital-to-analog conversion interface, and each signal and node is shown in Table 2.

Table 1: Definition of LPT4.

Pin	Name	Effect
1	!STR	RST
2	D0	CLK
3	D1	SDI
4	D2	LDA
5	D3	LDB
6	D4	CS1
7	D5	CS2
8	D6	CS3
9	D7	CS4
14	!ALF	CS5

3.3. Software Design of HIL Platform of Automotive ACCS System. Figure 3 shows the software background structure of automotive ACCS, and its program is implemented in C language on the basis of hardware design [17]. Each module of each layer output functions and data to its previous layer, and the lowest 3 layers exist in the basic system and are not generated in the application process.

Other basic functions are explained as follows:

(i) Main: the main application module, including the main application code entry, program control flow and user interaction functions.

(ii) Schedule: output functions and data to the DOS scheduler.

(iii) Ports: it provides definitions and functions for emulated parallel ports.

(iv) Sensors: pnterface functions for sensors and implementers.

(v) Motorway_Sim: road condition simulation data and function requirements.

(vi) Host_Car: it executes nonlinear dynamic modules under simulated road conditions.

(vii) Console: some simple control functions.

(viii) User_Interface: it executes boot menu, runtime information menu, and data interface.

3.4. Simulation of Car Motion. In order to make the simulation model of the car closer to reality, the dynamics of the whole vehicle, tire dynamics, and transmission of the vehicle must be considered. The car model can be simplified to a single-wheel model, a two-wheel model, and a four-wheel model, and acceleration/braking performance analysis is added. When the vehicle is driving on the highway, the lateral force of the vehicle is in general relatively small and has little effect, it can usually be ignored in order to simplify the system. When the lateral forces of the vehicle are not considered, it is most appropriate to use the two-wheel model vehicle for longitudinal vehicle dynamics simulation. Considering gravity, we assume that the center of gravity of the vehicle is approximately at the geometric center of the vehicle [18].

Table 2: Definition of LPT4.

Features	Order	Node	Pin
SDI	Vout9	RRWheel_Node	P0.27
RST	Vout8	RLWheel_Node	P0.27
LDA	Vout7	FRWheel_Node	P0.27
LDB	Vout6	FLWheel_Node	P0.27
CS1	Vout5	Throttle_Brake_Sensor_Node	P0.27
CS2	Vout4	Throttle_Brake_Sensor_Node	P0.28
CS3	Vout3	ACC_Sensor_Node	P0.27
CS4	Vout2	ACC_Sensor_Node	P0.28
CS5	Vout1	Vehicle_HMI_Node	P0.27

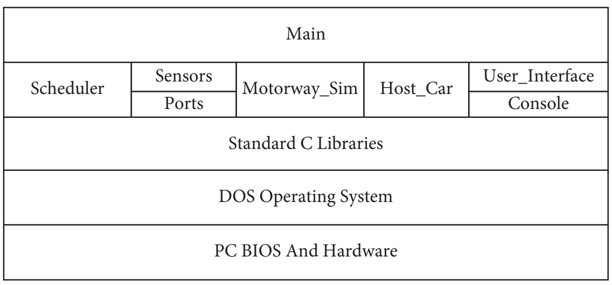

Figure 3: The software hierarchy of ACCS.

Suppose the total mass of the vehicle is m, there is a longitudinal velocity V in the X direction, the wheel speed angular velocity is ω_i, the wheel radius isR_i, and the moment of inertia is J_i, the subscripts f and r represent the front and rear wheels, respectively, the friction coefficient between the tire and the ground is u_i, the distance between the front and rear wheel axles is L, and B and C are the distances between the front and rear axles and the center of mass of the vehicle, respectively, the slope angle of the road isθ, and H is the height of the center of mass from the ground.

The longitudinal force F_{X_i} (X-axis direction) on the vehicle body mainly comes from the contact point between the tire and the ground. This force can either be a driving force or a braking force, which is proportional to the normal pressure F_{Z_i} of the vehicle to the ground, and μ_i is the adhesion coefficient.

$$F_{X_i} = \mu_i F_{Z_i}, \quad i = r, f. \tag{1}$$

Because there are four front and rear wheels, the superimposed resultant force F_{X_i} is the following formula:

$$F_{X_T} = 2 \times F_{X_f} + 2 \times F_{X_r}. \tag{2}$$

The relationship between the various forces acting on the vehicle body is the following formula:

$$\dot{V} = \frac{-F_{X_T} + mg\sin(\theta) - F_d(V)}{m}. \tag{3}$$

Among them, $mg\sin(\theta)$ is the slope sliding force, $F_d(V)$ is the resistance, including sliding friction resistance and air resistance. The normal pressure of each tire to the ground is the following formulas:

$$F_{Z_f} = mg\left(\frac{C}{L}\cos(\theta) + \frac{H}{L}\sin(\theta)\right) - m\dot{V}\frac{H}{L}, \tag{4}$$

$$F_{z_r} = mg\left(\frac{B}{L}\cos(\theta) - \frac{H}{L}\sin(\theta)\right) + mV\frac{H}{L}. \tag{5}$$

The calculation formula of $F_d(V)$ is the following formulas:

$$F_a = \frac{1}{2}\rho A C_d\left(V^2\right), F_r = mgC_r(V), \tag{6}$$

$$F_d = F_a + F_r. \tag{7}$$

Among them, F_a is the air resistance, F_r is the friction resistance, C_r is the sliding friction coefficient, A is the forward cross-sectional area of the vehicle body, C_d is the air resistance coefficient, and the air density p is 1.23 kg/m^3, the direction and magnitude of the wind also partially affects air resistance.

4. Results Analysis

4.1. Simulation System. A typical control system can be divided into three main parts: Sensors (sampling), control algorithms, and actuators. The sensor is responsible for sampling the data of the simulated car model (mainly speed); The control algorithm calculates and processes the sampled data; and the actuator sends the control output signal (throttle valve opening) back to the car simulation model (PC simulation program), change the operating state of the system [19].

(1) Single-node simulation system: In a single-node CCS control system, three functional modules are concentrated in one node, and the embedded control terminal completes all functions of sensors, controllers, and actuators by one node [20].

(2) Two-node simulation system: The CCS embedded distributed control system composed of two nodes is composed of two LPC2119 chip ARM7 boards, and the two nodes are connected by a CAN bus. One node is used to implement the sensor sampling function (node 1), while the other node is designed as a controller/actuator integration node (node 2). Node 1 will sample the car simulation model data and then it is transmitted to node 2 through the CAN bus; node 2 is based on the speed of the car model sent by the CAN bus and the set speed provided by the user, the required throttle opening is calculated by PID, and then returned to the simulation terminal of the car model through an 8 bit data line. Figure 4 is a block diagram of a dual-node control system.

Since single-node and dual-node simulations are relatively simple, in addition to being able to reflect some time-triggered scheduling and improve the performance of network protocols, it is difficult to achieve the realistic level of car motion simulation. The ten-node ACCS control system can more realistically simulate the actual vehicle system [21].

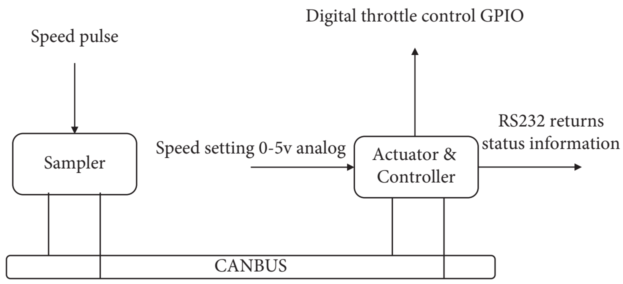

FIGURE 4: Block diagram of distributed dual-node control system.

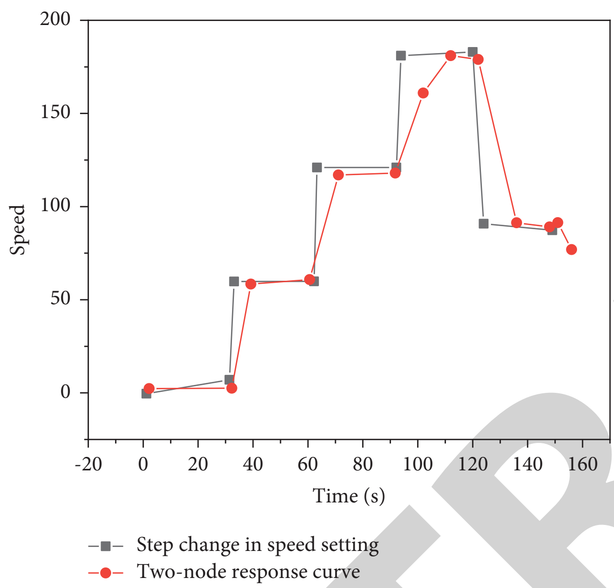

FIGURE 5: Simple-CCS constant speed single and double node speed response comparison.

4.2. Comparison of Simulation Results. Figure 5 shows the centralized control of a single node and the distributed control of two nodes, a comparison of the vehicle speed cruise control is performed. The performance of single node and double node in response to step change is basically the same, where the dotted line represents the step change of speed setting, and the solid line is the response curve of the two nodes [22].

Figure 6 is the comparison of the throttle control amount of the single node and the double node, the solid line is the single node control amount curve, and the dashed line is the double node control amount curve [23]. As can be seen from Figure 6, there is a big difference in the output of single-node and dual-node throttle control, the reason is that there is a network in the dual-node control loop, the carrying capacity and communication bandwidth of the network are limited,

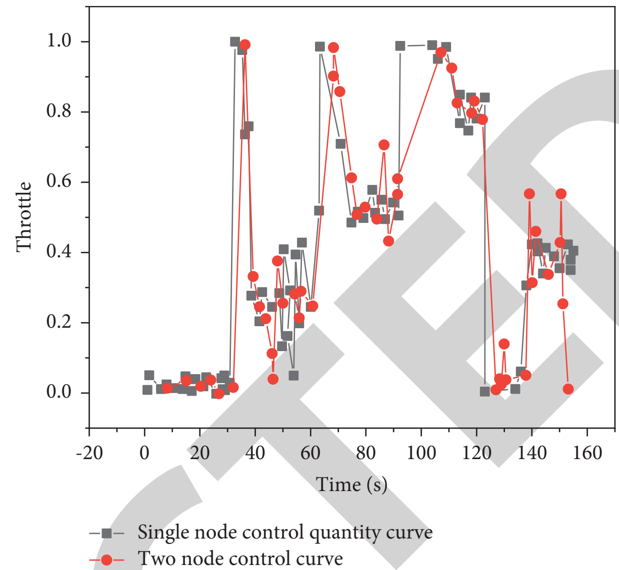

FIGURE 6: Simple-CCS constant speed single and double node throttle control quantity comparison.

which will inevitably cause information collision and retransmission, there is inevitably a delay in the process, and the delay is about 4.5 seconds [24, 25].

5. Conclusion

In today's society, the application fields of automotive electronics are very extensive, which have produced great social benefits and also stimulated the development of the automotive industry and automotive control. Combining with social needs, the author breaks the traditional idea of pure software simulation, starts with the embedded platform, introduces the overall design process of ACCS, opens up the design ideas of ACCS, and also lays a foundation for future research in related directions. of inspiration. There is a big difference in the output of single-node and dual-node throttle control, the reason is that there is a network in the dual-node control loop, the carrying capacity and communication bandwidth of the network are limited, which will inevitably cause information collision and retransmission, there is inevitably a delay in the process, and the delay is about 4.5 seconds. The next step will be to do further research on the control algorithm and communication protocol, and then comprehensively improve the control effect and safety and reliability of the system.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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