Research on Intelligent Vehicle Platoon Driving Experiment System Based on Wireless Communication

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***Abstract*—Intelligent vehicle platoon driving is a process of the flexible formation based on the coordination between vehicle and infrastructure in the intelligent vehicle-infrastructure system, which can increase the density of road traffic, simplify the complexity of traffic control, increase the controllability of traffic and ease the traffic jams. It has been constructed that the intelligent vehicle platoon drive simulation experiment system using the technology of one-tenth of intelligent vehicle and simulated road and wireless communication networks and so on. It also has been studied that the autonomous driving technology of intelligent vehicle and wireless communication between intelligent vehicles as well as the information interaction with the main console by the wireless communication module, providing technical and experimental basis for further research on vehicle platoon driving control under the coordination between vehicle and infrastructure.**

Keywords-Intelligent vehicle-infrastructure system; coordination between vehicle and infrastructure; wireless communication; vehicle platoon driving

I. INTRODUCTION

Intelligent vehicle platoon control system under the coordination between vehicle and infrastructure, on the basis of its great importance to the elements of the transport system, through increasing the intelligent control level of single vehicle, enhance the density of road vehicles and achieve the purpose of increasing road capacity[1]. Nowadays, Although the theories of vehicle platoon in architecture, behavioral characteristics, as well as intelligent traffic control algorithms are not perfect, with the development of wireless mobile network technology and wireless sensor network technology recently, there have enough technical support for realizing real-time information transmission and interaction between road and vehicles[2-4]. Guangming. Sun, Wuqing[2005] studied the wireless communication technology in vehicle monitoring and dispatching, focusing on making a comprehensive Comparison with the advantages and disadvantages of various means of communication from the view of real-time, safety and reliability on information to send and receive[5]. Therefore, this article selects DSP as master chip, constructs the intelligent vehicle platoon drive simulation experiment system based on wireless communication, which provides technical and experimental basis for developing the intelligent vehicle-infrastructure system, and achieving intelligent vehicle platoon driving control under the coordination between vehicle and infrastructure.

II. DESIGN OF THE INTELLIGENT VEHICLE PLATOON DRIVE SIMULATION EXPERIMENT SYSTEM BASED ON WIRELESS COMMUNICATION

The intelligent vehicle platoon driving simulation experiment is a process that simulates intelligent vehicle platoon driving and completes vehicle-vehicle and road-vehicle information exchange by the established wireless communication networks. This system consists of three parts: road sand table subsystem, intelligent vehicle platoon simulation subsystem, and the road-side information gathering and monitoring subsystem. The road sand table subsystem, as shown in Fig. 1 (a), consists of 1:10 closed road which simulates various freeway infrastructure.

The road-side information gathering and monitoring subsystem includes vehicle position detection module, platoon speed measurement module, wireless transceiver modules, wireless network of monitoring server and so on.

(a) (b)

Figure 1. (a) 1:10 road sand table simulation platform. (b) Intelligent vehicle simulation system.

The intelligent vehicle platoon simulation subsystem, as shown in Fig. 1 (b), includes DSP controller, power conversion module, motor drive module (MC33886), ZIGBEE wireless communication module, CMOS digital camera, infrared obstacle sensors, ultrasonic sensor, rotary encoder. Lateral information is acquired by using camera

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and infrared sensors, used to control the steering gear; speed of the intelligent vehicle is regulated by speed sensor, distance between the driving platoon is measured by ultrasonic sensor; vehicle-vehicle and road-vehicle information interaction are realized by ZIGBEE wireless communication module.

III. METHOD OF THE AUTONOMOUS DRIVING TECHNOLOGY OF INTELLIGENT VEHICLE

The study of the autonomous driving technology of intelligent vehicle has been divided into the research of latteral control and longitudinal control, which is the basic condition for achieving the intelligent vehicle platoon driving. The former mainly studies the tracking capability of intelligent vehicle, that is, how to control it driving along the road lane markings; the latter focuses on the speed closed-loop control, so that the intelligent vehicle drives stable on the road. In addition, internationally, the single vehicle control technology is more mature in the study on the intelligent vehicle-infrastructure system[6-7]. The autonomous driving strategy for the intelligent vehicle, around the hardware platform of intelligent vehicle, mainly studies the relationship between the steering angle and the road lane markings, and that between slope angle and speed, as well as the relationship between the factors mentioned above.

A. Latteral Control

Intelligent vehicle hardware platform sets up the tracking and obstacle avoidance strategies based on CMOS digital camera using OV6620 chip and infrared sensors assisted to avoid obstacles. The 1-8 pins of Ov6620 chip is the output for the 8-bit gray-level signal; 14 pin outputs row interrupt signal; 16 pin outputs field interrupt signal;18 pin outputs pixel sync signal. The field interrupt signal is to determine whether an image is started, the row interrupt signal is to determine whether the beginning of the image, the pixel sync signal is collected to determine the validity of the gray value. The CMOS digital camera collects a frame of image and determines the ranks of each frame image, that is, the number of pixels point, controlling the steering gear by calculating the deviation between the scope captured by camera and the vision of the location of the road lane markings.

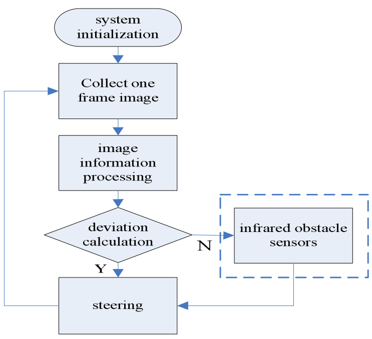

Figure 2. Intelligent vehicle latteral control strategy.

As there have been some problems under different road conditions, such as tunnels, big bend, and the shadow of the road, which results in hardly tracking road lane markings, the infrared sensors to avoid obstacles have been introduced to auxiliary judge so as to optimize the intelligent vehicle latteral control strategy. The strategy is shown in Fig. 2.

B. Longitudinal Control

In the study of the longitudinal control, Intelligent vehicle uses rotary encoder acquires speed every 200 millisecond, compared with a given speed, calculates the deviation and the discrete values of deviation differential and integral, as the put of the classical PID controller, the output value of controller, calculated by using the classical incremental PID control algorithm (1), through the motor drive module (MC33886), control motor and regulates speed of Intelligent vehicle.

$$\begin{cases} u(k)=u(k-1)+\Delta u(k) \\ \Delta u(k)=K_P(e(k)-e(k-1))+K_I e(k)+K_D(e(k)-2e(k-1)+e(k-2)) \end{cases} \quad (1)$$

Where, K_P, K_I, K_D are proportional, integral and differential coefficient.

In the intelligent vehicle platoon driving, ultrasonic sensors have been added to detect vehicle spacing. The output range of ultrasonic sensor, URM37V3.2, is 4cm-500cm. Its output model is Pulse Width Modulation (PWM). After observation from the oscilloscopes and calculation, 4cm corresponding PWM cycle is 2.6ms, from every 1cm increase in cycle 0.1ms. Therefore, the relationship established between the distance x and the cycle t is:

$$t=2.6+0.1(x-4) \quad (2)$$

In this way, the distance is calculated through the PWM cycle at some point obtained from the capture function in DSP controller and (2). The longitudinal control diagram of the intelligent vehicle is shown in Fig. 3.

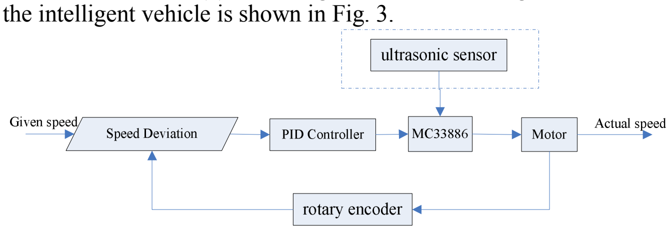

Figure 3. Longitudinal control diagram of the intelligent vehicle.

IV. INFORMATION INTERACTION BETWEEN VEHICLE AND INFRASTRUCTURE

The intelligent vehicle platoon drive simulation experiment system obtain information about single vehicle through vehicle sensor system and vehicle platoon through road-side sensor system， achieve information interaction between them by wireless network, and send these information obtained by them to the controlling central, realizing the multi-source information integration and test in the situation of vehicle road coordination by using prior knowledge, as shown in Fig. 4[8-10].

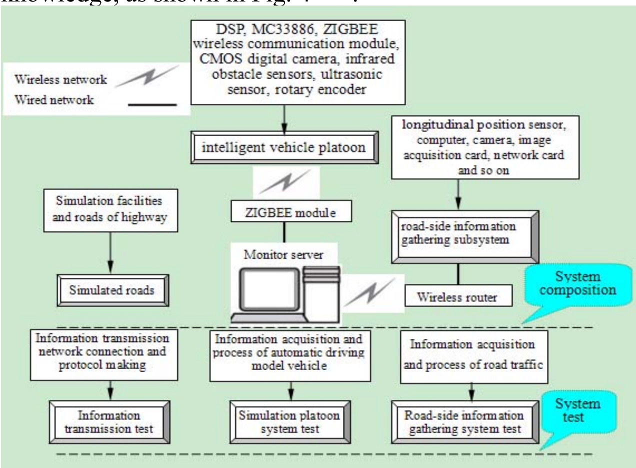

Figure 4. Process of information interaction between road and vehicles.

A. *Vehicle-Vehicle Communication*

Intelligent vehicles achieve wireless data exchange each other by ZIGBEE module. ZIGBEE module connects with DSP of the intelligent vehicle through the serial port of DSP as well as a computer, setting up a wireless communication network. ZIGBEE module can set network flexibly by themselves without manual intervention, and have three types of nodes: central node, relay route, and terminal node, the nodes can perceive other nodes and to determine connection style. In the design, firstly the lead car needs to be set as central node , other cars are set as relay route, with different ID number that sign different car; and the serial baud rate is set as 9600b/s, and set ZIGBEE wireless network module with the same letter 0x0F, that is, 2.480GHz; finally transmission mode is chosen of destination address .System send packets of different number to achieve vehicle –vehicle wireless communication. On this basis, frame formats are as follows considering the accuracy of data transmission:

Frame start flag	Identifier field	Data field	End frame flag

Among them, the Frame start flag is the number of electric vehicles, the hexadecimal FF express the end frame flag. The length of identifier is one byte (8 data bits), consisting of a 4-bit identifier type field and a 4-bit check field. Identifier type field include speed of intelligent car, steering, location and spacing, and so on. Identifier check field detect the errors of type field which generate from anti-code of each bit of type field, ensuring the reliability of indicators decoding. Data field contains a hexadecimal number, high bit in the front and low bit in the post. In accordance with the data types of identifier field, the corresponding values can be obtained from data fields, which ensure the accuracy of sending and receiving data. The software flow chart of sender and receiver as showed in Fig. 5.

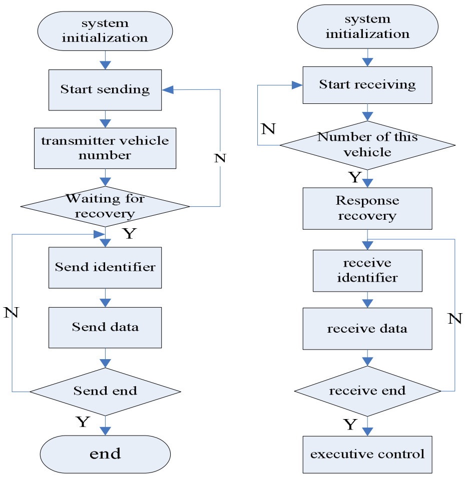

Figure 5. Software flow chart of sender and receive.

B. *Road-Vehicle Communication*

Road-side information gathering subsystem, through the road-side sensors system or ZIGBEE module, receives the information of intelligent vehicle platoon uses wireless routers with control centers for data exchange, completing with adapting network Socket programming. As a result of the local area network to send and receive data, it's best to choose UDP protocol transmission, preparation of procedures for the sending program, the first step is to load socket library , followed by Creating and initializing the socket, attention must be paid before sending, binding socket first. The receiving program, too, must be set to the same port, Otherwise data will be failed to receive. Procedures for the preparation of programming have been divided into two parts:

The first part of server-side

- The creation of server-side socket (create).
- Server-side socket bind information (bind), and began to monitor connection (listen).
- Accept connections from the client request (accept).
- The beginnings of data transmission (send / receive).
- Close socket (close socket).

The second part: the client program

- Create a client socket (create).
- Connections with server-side (connect), when accepted and then create the receiving process.
- The beginnings of data transmission (send / receive).
- Close the socket (close socket).

V. Design of the Control Interface Software of Main Console

It's necessary for the intelligent vehicle-infrastructure system to achieve information interaction among the intelligent vehicle platoon and the road-side information gathering and monitoring system, and is also an important foundation to the achievement of the intelligent vehicle platoon driving. In order to improve the level of intelligent control of the single vehicle, as well as the ability of the information interaction among traffic environment. The control interface software of main console based on wireless communications by the ZIGBEE module has been designed, as shown in Fig. 6. It uses the control of MSCOMM in Visual C + +, provides an easy way to send and receive data for applications through the serial port. The software can be used for intelligent control of the single vehicle, and also be used for stop-and-go control, sequence control for double intelligent vehicles; and at the same time to receive the speed, steering, location and other information of the intelligent vehicles, which is easy to adjust control strategies online, analyze data and store information.

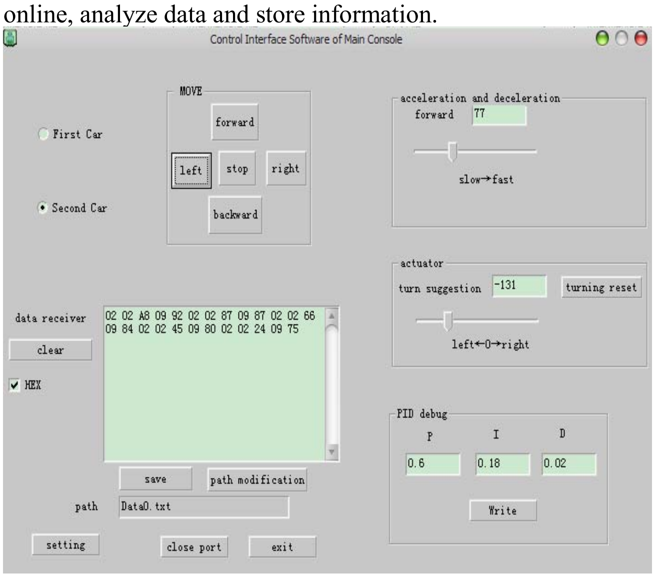

Figure 6. Control Interface Software of Main Console.

VI. CONCLUSION AND PROSPECT

Vehicle platoon control under the intelligent vehicle-infrastructure system is one of hotspots in recent research field of intelligent transportation, where hardware-in-the-loop simulation technology is the important research means. In this paper an intelligent vehicle simulation system is put forward, the composition of the system and each part's functions are described. This paper proposes the control strategy of the intelligent vehicle, designs wireless communication systems based on ZIGBEE module, completes stop-and-go, sequence control and communications of double vehicle, as well as information interaction between the vehicles and the main console, which provide technical and experimental basis for further research on vehicle platoon driving control under the coordination between vehicle and infrastructure. The next works are as follows:

- In the lateral control, the image processing algorithm continues to be improved, landmark recognition will be chosen to navigate, rather than a special road lane markings.
- In the longitudinal control, a simple, accurate vehicle dynamics model still needs to be pursued, and the vehicle needs to find smart and efficient control methods.
- In vehicle platoon control, the stability conditions of the platoon continues to be analyzed, high-fault-tolerant control algorithm for the platoon is going to be explored.

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