Intelligent Vehicle Platform and Signal Processing Method Applied to Cooperative Vehicle Infrastructure

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ABSTRACT

The technology of intelligent cooperative vehicle infrastructure helps to improve road traffic safety and efficiency. The intelligent vehicle platform is the key equipment for research and validation of the technology of intelligent cooperative vehicle infrastructure. First, the general requirements of intelligent vehicle platform as well as the platform vehicle motion and the way of gaining status information based on external sensors are introduced with a focus on the signal filtering and calibration of vehicle sensors. The intelligent vehicle platform established is demonstrated to gain status information of vehicle motion accurately through a comparison test and becomes the key device for the intelligent cooperative vehicle infrastructure research.

1. INTRODUCTION

The automobile industry has made great development with the rapid development of economy. Automobiles bring great convenience to people's travel, at the same time, it leads to serious traffic congestion and safety issues. Intelligent Transportation System (ITS) as required to solve the increasingly serious urban road traffic problems effectively. As the key technology of ITS, cooperative vehicle infrastructure system (CVIS) has attracted more attention from western developed countries and recently, China also began to study this aspect actively.

CVIS gains vehicle and road information based on the technologies of wireless communication, sensor detection, realizes the intelligent coordination and cooperation between vehicle and infrastructure by the means of vehicle to vehicle and vehicle to infrastructure communication, and achieves the goals of using system resources optimally, improving road traffic safety and easing traffic congestion (Chen et al, 2003). Intelligent vehicle platform is a test platform of carrying on the technology of intelligent cooperative vehicle infrastructure research. First the general requirements of intelligent vehicle platform are introduced, then a method of signal collection and processing of vehicle motion status is put forward, and finally the availability of the collected vehicle motion status signal is analyzed.

2. OVERALL PLAN AND INTEGRATION OF INTELLIGENT VEHICLE PLATFORM

2.1. Overall plan of intelligent vehicle platform

Design ideas of test vehicle platform should meet the requirements of vehicle's basic function. There are three detailed requirements: first it should have common driving ability when it is independent of CVIS; second it should have target recognition and longitudinal active collision avoidance abilities when it is independent of vehicle infrastructure communication system; third it should have safe intersection pass, active collision avoidance and adaptive vehicle speed when CVIS works.

According to the above ideas, design requirements of intelligent vehicle platform are as follows:

a) In addition to the original vehicle controller area network (CAN) bus information, sensors of longitudinal acceleration, lateral acceleration, yaw-rate and steering wheel angle are increased to perceive vehicle motion status, at the same time, millimeter-wave radar and on-board camera are increased to perceive front vehicles and pedestrian status, wireless communication equipment and differential-global positioning system (D-GPS) are increased to perceive transportation and road information, self-vehicle and adjacent vehicles state. In-vehicle information is mainly communicated by CAN bus and serial communication is used between vehicles and mobile equipment.

b) Modification of brake pedal and accelerator pedal cannot destroy original vehicle function, at the same time, it can provide an automatic control solution when CVIS works.

c) Modification of electrical system should ensure that all the equipment work normally in case of no external power source, meanwhile should ensure system electrical safety.

d) The collected information of radar, video and communication equipment will be as a basis for calculating time to position conflict (TTPC).

Therefore, CVIS is able to work both independently and cooperatively after modification of test vehicle.

2.2. Integration of intelligent vehicle platform

Intelligent vehicle platform integrates vehicle inertial sensors and driving environment perception sensors, signal acquisition and processing module and actuator controller, signal fusion algorithm and system control algorithm and so on.

Vehicle inertial sensors consist of sensors of longitudinal acceleration, lateral acceleration, yaw-rate and steering wheel angle, and they are mainly used to perceive vehicle motion status. The performance of sensors of longitudinal acceleration, lateral acceleration and yaw-rate used are shown in table 1 below. The detection angle range of steering wheel angle sensor modified is $-899.9deg$~$900.0deg$ and its resolution is $0.1deg$, the output is CAN signal and its bit rate is 500 Kbps, the signal transmission cycle is 10ms. The steering wheel angle sensor has long life and high resolution with faults self-check function.

Table 1. Vehicle sensor performance

Sensor Type	Sensor Range	Sensor Sensitivity	Output Voltage
Longitudinal Acceleration	$\pm 2.0g$	$1000mV/g$	$0\sim 5V$
Lateral Acceleration	$\pm 1.8g$	$1000mV/g$	$0\sim 5V$
Yaw-rate	$\pm 100deg/s$	$18mV/(deg/s)$	$0\sim 5V$

Vehicle on-board equipment contain radar, camera, D-GPS, wireless communication equipment and electronic vacuum booster (EVB), and they are mainly used to perceive adjacent vehicles and pedestrian status, acquire transportation and road information and provide information for controlling vehicle driving.

Master controller's function is to collect sensor signals and convert them to CAN signal; collect radar CAN signal and identify front and back vehicles at the same lane; collect original car signal. All the signals collected are sent to system CAN.

The function of EVB and electronic throttle controller is to collect brake pressure and accelerator pedal position signal, and provide control signal for EVB by gaining TTPC from system CAN.

Human-machine Interface (HMI) is to warn driver with auxiliary prompt such as speech, image and light by collecting and processing the warning information from CVIS software. The integration solution of intelligent vehicle platform system is shown Fig.1.

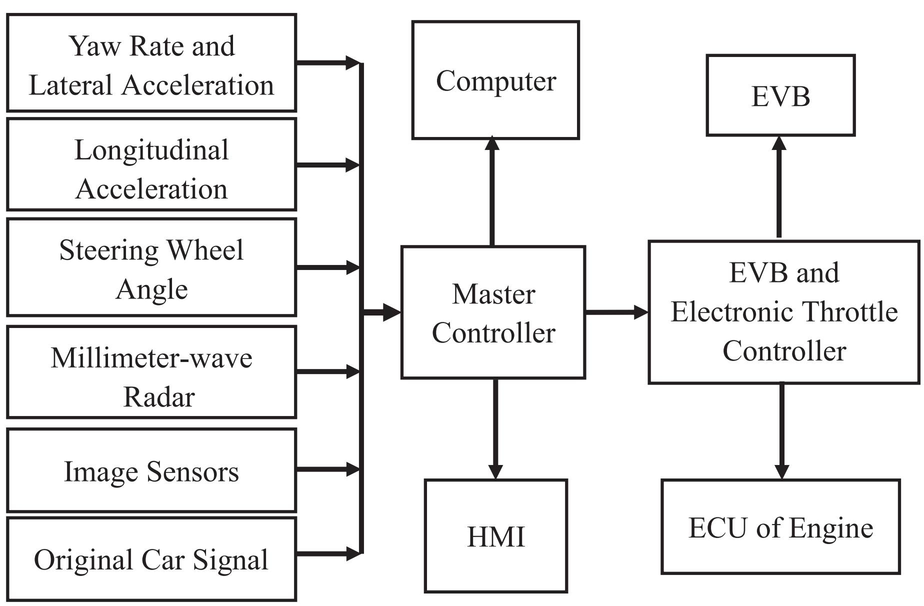

Figure 1. Integration solution of intelligent vehicle platform system

3. Signal collection and processing of vehicle motion status

Sensors of longitudinal acceleration, lateral acceleration, yaw-rate and steering wheel angle are installed on the test vehicle to perceive vehicle motion status. Vehicle motion state information is collected by AutoCAN and processed using following method.

3.1. Vehicle sensor signal filtering

The output signal noise of installed sensors of longitudinal acceleration, lateral acceleration and yaw-rate is relatively big, so in order to reduce the noise disturbance, the collected signal needs to be filtered.

Kalman filter is a kind of optimized autoregressive data processing algorithm, and it has high efficiency and good filtering effect. Kalman filtering algorithm is widely used in the fields of robot navigation, control, sensor data fusion, radar system, missile tracking, image processing, etc. (Deng et al, 2003). The filtering principle formulas used in the Kalman filtering of vehicle sensor signals are as follows (Jiang, 1993), (Zhang et al, 2012).

$$\hat{x}(t+1|t+1)=\hat{x}(t+1|t)+K(t+1)\varepsilon(t+1) \quad (1).$$

$$\hat{x}(t+1|t)=\hat{x}(t|t) \quad (2).$$

$$K(t+1)=P(t+1|t)[P(t+1|t)+R]^{-1} \quad (3).$$

$$\varepsilon(t+1)=y(t+1)-\hat{x}(t+1|t) \quad (4).$$

$$P(t+1|t)=P(t|t)+Q \quad (5).$$

$$P(t+1|t+1)=[1-K(t+1)]P(t+1|t) \quad (6).$$

The collected vehicle sensor signals can be filtered according to the Kalman filtering algorithm above. Vehicle sensor signals were collected in many kinds of running case, and one case of start-steady steering-stop was chosen and the signals of longitudinal acceleration, lateral acceleration and yaw-rate were processed by Kalman filter. The filtering effect is shown in Fig.2, Fig.3 and Fig.4.

According to the filtering results of the three signals of longitudinal acceleration, lateral acceleration and yaw-rate, it can be seen that Kalman filter is appropriate for CVIS.

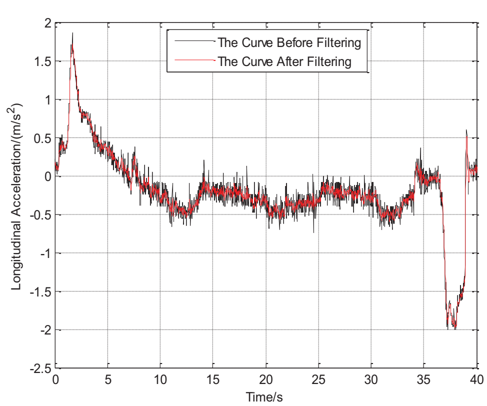

Figure 2. Filtering effect of longitudinal lateral acceleration

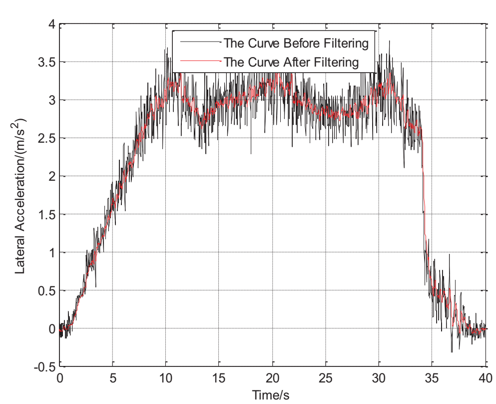

Figure 3. Filtering effect of acceleration

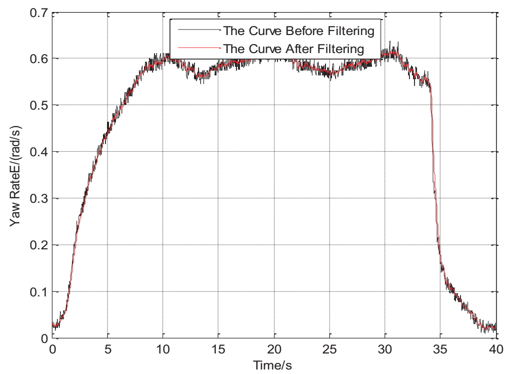

Figure 4. Filtering effect of yaw-rate

3.2. Analysis of vehicle sensor signal availability

In order to verify availability of longitudinal acceleration, lateral acceleration and yaw-rate signal, RT Inertial and GPS Measurement System was used, and its model is RT3100 in RT3000 series (RT3000 is called for short below). Algorithm, inertial sensor module and three angular speed sensors applied to fighter navigation system are used in RT3000 to calculate all output so as to achieve high precision measurements. Unlike common inertial navigation system, RT3000 uses GPS to correct all output so as to improve the measurement accuracy (Ji, 2004). The schematic of availability analysis is shown in Fig.5.

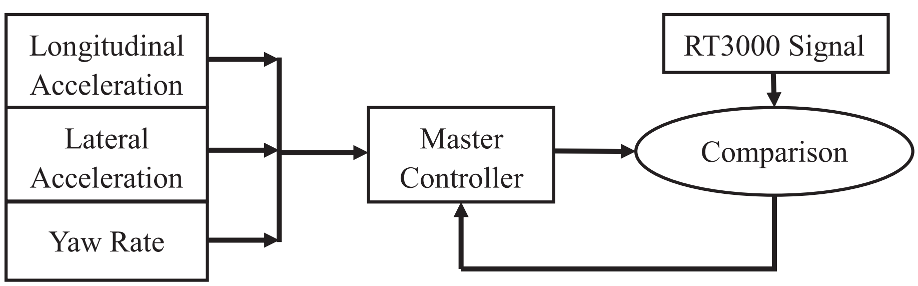

Figure 5. Schematic of availability analysis

In availability analysis test, the longitudinal acceleration, lateral acceleration and yaw-rate signal collected by AutoCAN was compared with RT signal, which was seen as accurate value. The comparison results are shown in Fig.6, Fig.7 and Fig.8.

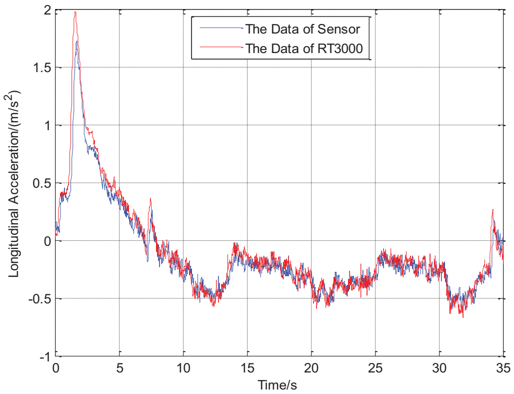

Figure 6. Comparison curve of longitudinal acceleration

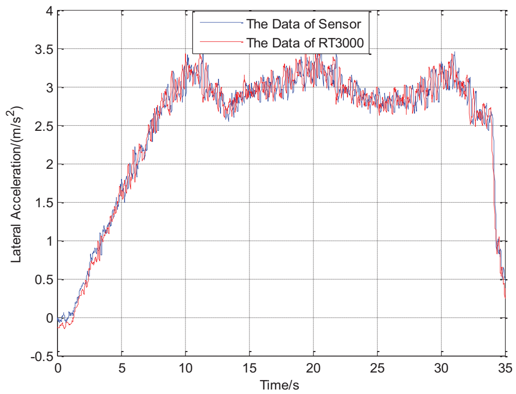

Figure 7. Comparison curve of lateral acceleration

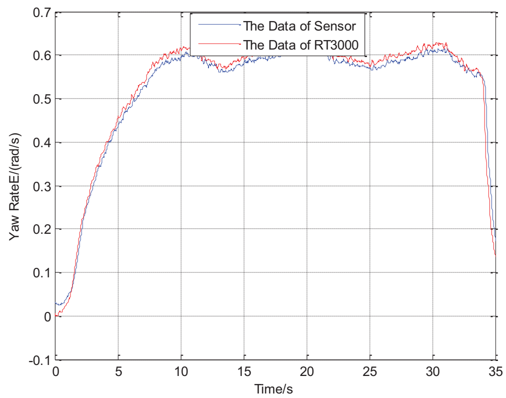

Figure 8. Comparison curve of yaw-rate

Through the comparison curves of sensor data and RT3000 data, it can be seen that sensor signals and RT3000 signals change consistently, and tracking is good without considering the condition of time delay error. Through the above analysis, the following conclusion can be drawn: the signal collected by sensors of longitudinal acceleration, lateral acceleration and yaw-rate is valid and it can reflect vehicle motion state accurately, it can provide reliable control information for CVIS.

4. CONCLUSION

Intelligent vehicle platform is set up for the research and application of cooperative vehicle infrastructure control technology and it can gain the information of self-vehicle, adjacent vehicle and road applied to CVIS efficiently. Vehicle motion status information is collected by AutoCAN, the signal noise is reduced by Kalman filter, and the availability of signal collected by sensors of longitudinal acceleration, lateral acceleration and yaw-rate is verified by RT3000. The construction of intelligent vehicle platform and method of data collection and processing lay a solid foundation for further study of CVIS, and will be significant for the research of CVIS.

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