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Model Construction of Sensor Configuration Scheme for Intelligent Networked Vehicles

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Abstract

In this paper, the concept of intelligent networked vehicle cloud control system based on cyber-physical system theory is proposed. The system uses a new generation of information and communication technology to integrate the physical layer, information layer and application layer of people, vehicles, roads and clouds to perform fusion sensor perception, decision-making and control. The system can achieve a comprehensive improvement in the safety and efficiency of vehicle driving and traffic operation. At the same time, this paper designs a multi-objective optimization method of sensor configuration based on genetic algorithm to solve the problem of redundancy and insufficient utilization of sensor configuration of assisted driving system under intelligent network connection. The system gives the optimization scheme of sensor installation position and configuration and carries out simulation analysis and verification. The performance of cloud computing, fusion perception, fusion decision-making and network-connected control of the system is verified through simulation and road tests. At the same time, the experiments in this paper show the feasibility and advanced nature of the system's practical application.

Keywords

Intelligent Network Connection; Automotive Sensor; Sensor Configuration; Genetic Algorithm.

1. Introduction

Automobiles are advancing towards the "new four modernizations" of electrification, intelligence, networking and sharing. With the improvement of intelligent ability requirements, vehicles need to have high-speed, reliable and safe computing capabilities, and they have gradually become a new type of mobile intelligent terminal. The in-vehicle intelligent computing platform is the "brain" of the vehicle, which is the concentrated expression of the vehicle's computing power. In the face of more complex functional requirements, the current vehicle intelligent computing platform usually adopts a new electronic and electrical architecture, with a domain controller (DCU) as the core, integrated vehicle electronic control unit (ECU), vehicle camera, ultrasonic radar, millimeter wave radar, Intelligent electronic terminals such as on-board communication terminals (OBU) and related software [1]. However, the complexity and unpredictability of the external environment and the stability of the system itself have brought great challenges to the security of the vehicle-mounted intelligent computing platform. Therefore, a lot of testing is required before the product is launched to ensure that it can operate normally in various environments, states and emergencies. The technological breakthrough of key components of intelligent networked vehicles is of decisive significance to promote the industrialization of intelligent networked vehicles. The lack of key technologies and the level lag are one of the bottlenecks restricting the development of intelligent networked vehicles [2]. Key components include sensors, positioning systems, advanced driver assistance systems (ADAS), and more. The three core components of the sensor include vehicle cameras, millimeter-wave radars and lidars. The optimal configuration

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of sensors for automotive multi-functional ADAS to achieve efficient system integration is the development direction of smart cars in the future. This paper proposes a sensor configuration optimization method for assisted driving. By designing the sensor optimization objective function and its constraints, the non-dominated sorting genetic algorithm with elite strategy is used to comprehensively optimize the sensor configuration scheme. Finally, the optimal configuration is optimized by PreScan software. Case studies to verify the feasibility of the method.

2. Architecture of Intelligent Networked Vehicle Cloud Control System

The intelligent networked vehicle cloud control system proposed in this paper is an integrated optimization system for intelligent networked vehicles and transportation with the cloud control platform as the core. The cloud control system consists of a cloud control platform, roadside infrastructure, connected intelligent vehicles, communication network and resource platform. Its basic architecture is shown in Figure 1. The communication network connects people, vehicles, road and cloud nodes, and the connected intelligent vehicles, roadside infrastructure and resource platforms are connected to the cloud control platform.

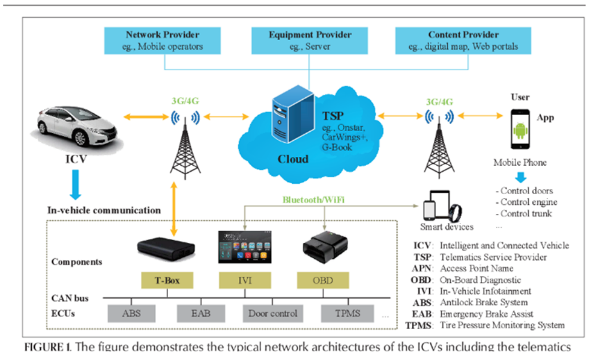

Fig 1. Basic architecture of intelligent networked vehicle cloud control system

The overall technical architecture of the design cloud control platform is shown in Figure 2, focusing on the following four aspects. In order to break the current predicament of vehicle-road cloud forming an information island, the cloud control system uses a unified standardized mechanism for vehicle-road-cloud communication to achieve efficient and extensive interconnection and high-performance transmission [3]. The cloud control platform utilizes advanced technologies such as software-defined network and network function virtualization to monitor and predict communication requirements and network status in real time, and to realize dynamic regulation of the communication process between the cloud control platform and the communication network, so as to improve communication efficiency and reliability.

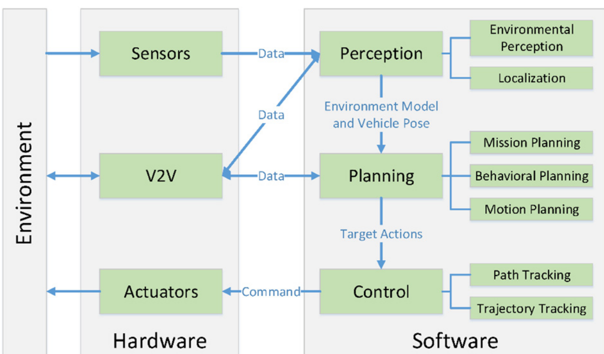

Fig 2. Overall technical architecture of cloud control platform

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Connected smart cars connect the cloud-based basic platform, roadside infrastructure and other vehicles, share vehicle-side data, receive the output of collaborative applications and respond. The connected smart car is the data source and controlled object of the cloud control system. The cloud control system not only directly improves the driving performance of the connected smart car, but also uses the connected smart car to optimize the behavior of the mixed traffic in which it is located.

2.1. Sensor Simulation

Sensors are tools for perceiving the world in an in-vehicle intelligent computing platform and an important functional component to support intelligent driving. Sensor simulation can incorporate most of the functional modules of the intelligent driving vehicle end system into a closed loop to achieve more complete and comprehensive test verification [4]. Sensor simulation is usually a simulation of its real-time data. Mainstream sensors mainly include lidar, ultrasonic radar, camera and inertial measurement unit IMU. During the simulation process, the simulator needs to be optimized so that it can realize real-time data output. Compared with traditional simulators that only support offline simulation, real-time systems have higher efficiency and better user experience, and what you see is what you get.

2.2. Event Monitoring and Determination

Using humans to monitor the behavior of a large number of vehicles is difficult in large-scale simulation tests. Therefore, the simulation test needs to have the vehicle behavior monitoring function to automatically monitor whether the behavior of the target test system meets the expectations. On the basis of summarizing a large number of field test and simulation test experience, a batch of general system test result judgment conditions can be abstracted to form a complete behavior monitoring function [5]. However, since the test system judgment conditions will continue to increase with the needs of users, the function needs to have high scalability. Functional coupling should be avoided, and each abstracted behavior monitoring component should be regarded as an independent logical entity. In this case, the convenience of adding and removing behavior monitoring components can be improved, the system burden can be reduced, and the demand response speed can be improved.

2.3. Hardware Configuration

The simulation system inputs the real or virtual sensor digital signals into the domain controller; the domain controller performs planning and control calculations, and outputs the control-by-wire signal; the simulation system updates the virtual vehicle state and simulation results after receiving the control-by-wire signal, and simulates the simulation results [6]. The results are fed back to the domain controller. The overall hardware-in-the-loop framework is shown in Figure 3.

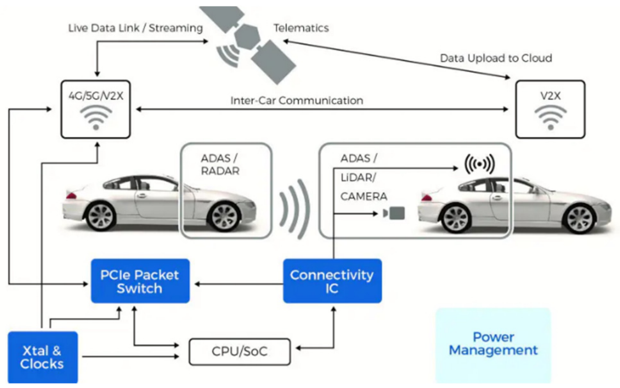

Fig 3. Hardware setup

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The key technology of hardware-in-the-loop is the simulation of sensors. Today, multi-sensor fusion is one of the mainstream solutions for in-vehicle intelligent computing platforms. It can be the fusion of multiple sensors of the same type, or the fusion of different types of sensors.

2.4. Camera Simulation

There are usually two ways to achieve camera simulation. One is to use real video to play in the video obscura to the real camera; the other is to directly transmit the traffic scene image information to the image processing unit through the camera radio frequency injection module (CSM) to replace the real camera to detect traffic.

2.5. Millimeter Wave Radar Simulation

Millimeter-wave radar simulation mainly down-converts the received RF signal through space-feeding and then transmits it to the centimeter-wave division system. Real-time distance simulation, speed simulation and RCS simulation are performed according to the target parameters injected by the system, and the analog signal is transmitted to the millimeter-wave radar [7]. Up-conversion module for WDM systems. After up-conversion, the corresponding target simulation echo is generated in real time, and then sent to the vehicle millimeter wave radar.

2.6. Ultrasonic Radar Simulation

Using ultrasonic echo simulation equipment (ultrasonic test box), the real ultrasonic sensor and sound transducer are arranged in it. The distance information of the obstacle is sent to the sound transducer by the simulation software, and the ultrasonic waves formed by the sound transducer are transmitted to the control unit by the ultrasonic sensor.

3. The Preferred Method of Sensor Configuration

The optimization of the sensor configuration needs to import the vehicle information and sensor information: the vehicle information includes the length and width information of the vehicle. Sensor information includes detection distance, viewing angle, distance accuracy, cost, reliability (MTTF) information.

3.1. Optimization Objective Function and Design of Constraints

In order to optimize the sensor configuration, it is necessary to establish the optimal evaluation index and system of the sensor, and quantify the advantages and disadvantages of the solution [8]. The sensor optimization objective function and constraints established in this paper are as follows:

1) Detection area coverage optimization objective function $J_1(X)$. The higher the detection coverage, the smaller the sensor blind area.

$$\begin{aligned} J_1(X) &= F(X)/S_r \\ F(X) &= \Sigma_{i=1}^{n} S_i - S_n \end{aligned} \tag{1}$$

In the formula, X is the set of n sensors configured. Each element value represents the sensor number. S_r is the target area to be detected. $F(X)$ is the effective area detected by this sensor ensemble configuration. S_i is the detection area of the ith sensor. S_n is the sum of the intersections of the detection areas of n sensors. The area S_i detected by the i sensor is usually obtained from the detection distance and angle of view of the sensor, and the constraints on the detection distance d and the angle of view φ of the sensor need to be established as shown in formula (2).

$$d_x \geq d_i, \quad \varphi_x \geq \varphi_i, (i \in 1,2,\ldots,n) \tag{2}$$

In the formula, d_x is the effective detection distance after configuring the sensor set X. d_i is the minimum detection distance requirement of the sensor at i number. φ_x is the effective viewing angle after configuring the sensor set X. φ_i is the minimum viewing angle requirement for the sensor at i number. n is the total number of sensors configured in the vehicle.

2) Detection distance accuracy optimization objective function J2(X), see equation (3). On the premise of meeting the measurement accuracy requirements, the higher the detection accuracy of the sensor, the better the control accuracy of the ADAS.

$$J_2(X) = \varepsilon_X^2 \tag{3}$$

In the formula, ε_X is the ranging accuracy error after the configured sensor set X, and its constraints are shown in formula (4).

$$\varepsilon_X \leq \varepsilon_i \tag{4}$$

In the formula: ε_i is the minimum accuracy required by the minimum detection distance of the sensor number i.

3) Cost optimization objective function $J_3(X)$ and constraints are shown in formula (5). Consider the acquisition cost of the sensor under the premise of meeting the performance requirements.

$$J_3(X) = \Sigma_{i=1}^{n} P_{X_i}, \ \Sigma_{i=1}^{n} P_{X_i} \leq P_{max} \quad i \in 1,2,\ldots,n \tag{5}$$

Where P_{X_i} is the acquisition cost of the sensor number i in the sensor set X. P_{max} The maximum price for the sensor configuration set cost.

3.2. Comprehensive Optimization of Configuration Scheme based on Genetic Algorithm

The comprehensive optimization of the configuration scheme is based on the vehicle and sensor information and the above objective functions and constraints, using a multi-objective global optimization algorithm to perform multi-objective optimization calculations on the sensor parameters and their installation positions, and give the optimized sensor configuration scheme (including installation location). The genetic algorithm is used to solve the problem to speed up the convergence speed in the search process [9]. Individuals with the same rank are retained according to the exclusion mechanism, which effectively protects the diversity of the optimal solution.

4. System Simulation Research

Based on the automatic driving scheme matrix, the RSM method can be further optimized to obtain the optimal configuration required by itself. For example, to obtain the optimal test results with the minimum cost and minimum false alarm rate, several sets of parameter ratios with the greatest satisfaction will be obtained through the table, that is, the sensor configuration scheme required by the user is shown in Figure 4.

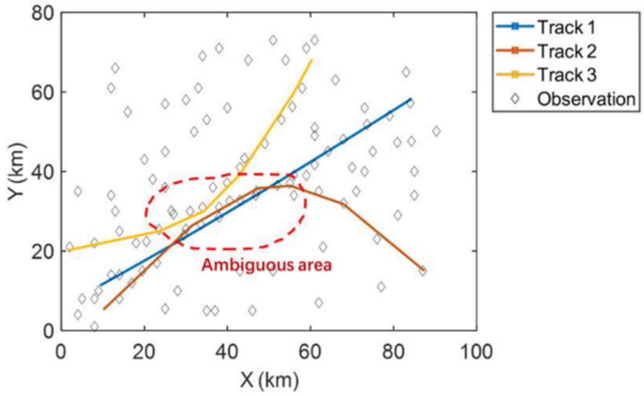

Fig 4. Simulation results of the sensor ensemble system

5. Conclusion

With the overall development of the domestic intelligent networked automobile industry and the promotion of national-level strategies, it will play a huge role in promoting the development of components in the sensing field. In this paper, an intelligent networked vehicle cloud control system with vehicle-road-cloud integration is proposed. The simulation found that (1) Different levels of automatic driving configuration schemes need to be selected according to the schemes entered in the database, form the basic configuration and increase as needed, and then set the rigidity for similar sensors based on the algorithm program in terms of accuracy, environmental adaptability, hardware cost, etc. Criteria for screening and optimization to determine the optimal model. In this way, other sensor models can be derived, and finally the sensor configuration scheme can be obtained. (2) Based on the current situation that there is no effective screening method for automatic driving sensor configuration, this paper establishes a database and uses genetic algorithm for optimal screening. However, the current scheme has certain defects and cannot systematically form a sensor configuration scheme. With the increasing demand for autonomous driving sensors, the database will continue to expand, and there will be more effective algorithm programs to meet user needs more quickly and conveniently.

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