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Vehicle Relative Positioning System Based on Vision and V2X

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Abstract: Obtaining the accurate position information of the vehicle is of great significance for the intelligent driving assistance system. Due to the relative positioning accuracy based on Global Positioning System is not high enough and the signal is unstable, and the positioning system based on wireless communication needs to lay a large number of roadside units, a relative positioning method based on vision and V2X is proposed. The error distribution of the positioning method is analyzed, and the positioning result is Kalman filtering. The results show that the relative positioning system can achieve positioning accuracy within 0.38m of the smooth straight road and 0.35m of the curved and large undulating road, and its positioning stability can be improved after Kalman filtering.

Keywords: Intelligent Transportation Systems; Relative Positioning; V2X; Vision

Introduction

With the development of vehicle networking technology in recent years, ITS application in intelligent transportation system (ITS) has gradually attracted attention, and vehicle positioning, as its key technology, serves applications such as vehicle queue control, vehicle collision avoidance, unmanned driving, etc. Therefore, obtaining high-precision vehicle relative position information is of great significance to the development of vehicle networking applications and intelligent transportation systems.

At present, the relatively common methods of vehicle relative positioning mainly include GPS based relative positioning and wireless communication based relative positioning. GPS relative positioning, i.e. differential positioning, is a method to determine the relative position between observation points according to the observation data of more than two receivers. However, its positioning accuracy is about 2m[1,2]. In an open environment, which cannot meet the requirements of intelligent driving assistance system. Document[3] proposes a vehicle relative positioning method based on GPS pseudorange double difference. Vehicles based on pseudorange double difference. The relative positioning algorithm can make its relative positioning performance significantly better than the relative position information measured by GPS single-point positioning. However, due to the satellite signal being easily blocked, the recovery time after signal loss is longer, and the positioning reliability is poor. Documents[4-11] proposes multi-vehicle cooperative relative positioning methods based on vehicle-vehicle communication and GPS.

At present, many researches are based on RFID to acquire traffic information such as vehicles and roads [11]and exchange the acquired information[12-13] through V2X communication. At the same time, distance measurement and positioning[14] are based on TOA and other principles. However, these positioning methods generally require at least three adjacent nodes to determine the location of vehicles according to the principle of trilateration. For sparse node environments, accurate positioning is not possible, and RFID is only applicable to the scene[15]with short transmission distance, in addition, there are some bases. The method[16] of 50 relative positioning based on the wireless signal strength of the smart phone, however, this positioning method can only determine the relative position relationship of the vehicles and cannot accurately position.

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1. Relative positioning method

The basic frame of this positioning system is shown in Figure 1, which is mainly divided into two working conditions: flat straight road positioning, curved road positioning and large undulating road positioning. Among them, the big undulating road refers to the road section with a large ratio of the height difference between two points of the same slope section and its horizontal distance on the vertical section of the road, i.e. the road section with a large longitudinal slope, where the road section with a longitudinal slope greater than 3% is defined as the big undulating road. For flat straight road conditions, its positioning is divided into horizontal positioning and vertical positioning, and the horizontal relative positioning is integrated by RFID and visual detection means that the determination of longitudinal relative position is completed by V2V communication. Working condition positioning of curves and rough roads is realized by V2I communication combined with vision.

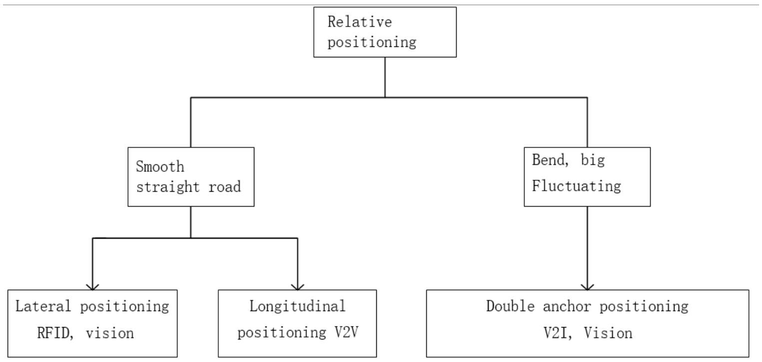

Figure 1. Positioning system framework.

1.1 Flat straight line positioning method

In the research of intelligent transportation system, many related positioning researches use sensors such as radar, laser and camera to obtain the required information. With the development of machine vision, cameras are increasingly used in ITS, and lane detection technology in road environment perception is becoming more and more mature[17].

In order to further obtain the accurate lateral position information of vehicles, this paper will detect the lateral distance between vehicles and lane lines and calculate the lateral coordinates after obtaining the distance information of surrounding vehicles by V2V communication. Here, firstly, the image acquired by the camera is subjected to inverse transflective transformation to obtain two intersection points of the extension line of the width line and the lane lines on both sides, and the distance value between the end point of the added width line and the left and right intersection points is calculated respectively, i.e. the distance value between the vehicle and the lane lines on the left and right sides. the calculation effect is shown in Figure 2. the median value of the width horizontal line in the figure is the lane number of the vehicle at this time, the left value is the distance value between the vehicle and the left lane line, and the right value is the distance value between the vehicle and the right lane line.

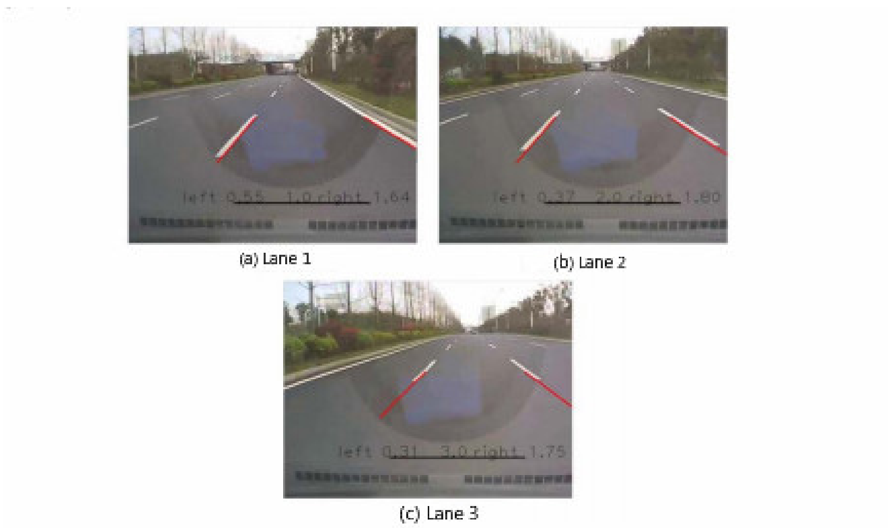

Figure 2. Horizontal Spacing Calculation Effect

After calculating the distance between the vehicle and the lane line, the information obtained through V2V communication is used to further calculate the lateral relative coordinate value of the vehicle. By comparing some wireless communication technologies commonly used in positioning, such as Zig-Bee, Bluetooth, WiFi and UWB, it is concluded that UWB signals have the advantages of high transmission rate, strong anti-interference capability, large system capacity and high multipath resolution. Therefore, the UWB communication module is used for communication and ranging [18-20] to obtain the spacing values of vehicles around the straight road. Two UWB communication modules are installed on the vehicle, respectively placed at the front end and the center of the vehicle and arranged in the same row, and the vehicle relative positioning coordinate system is established at the position of the vehicle center module, as shown in Figure 3.

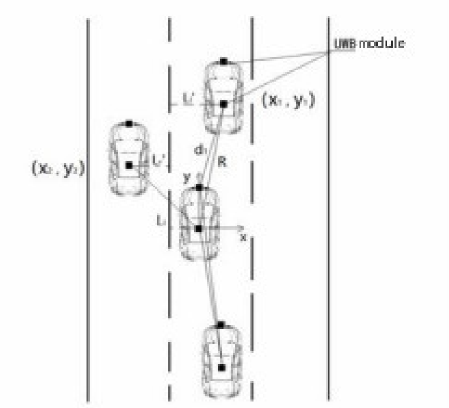

Figure 3. Smooth straight positioning principle.

1.2 Principle of relative positioning for curved roads and roads with large fluctuations

Analysis of the above positioning method shows that it is not suitable for curved roads and rough roads. This paper will base on V2I communication, visual perception and road electronic map to position vehicles relatively under curved roads and rough roads.

For curved road surface positioning, two RSUs are respectively arranged on both sides of the curved road entrance, the connection line of which is perpendicular to the straight road, and the curved road turn facing the curved road entrance perpendicular to the connection line of the RSU is recorded. The coordinate system is built on one of the RSUs, as shown in Figure 4(a). At this time, the recorded curved road turn is a right turn. The image of the road ahead is acquired by the camera, and the lane line of the curve and its turning direction are detected based on vision. The center UWB module of the vehicle communicates with the UWB modules on the two RSU and measures distance to obtain two distance value information.

For the relative positioning of vehicles on straight roads with large road surface elevation fluctuation, it is necessary to obtain elevation information by combining with road surface electronic maps. Two RSUs are respectively arranged on both sides of the entrance to the ground elevation rise. The coordinate system is built on one of the RSUs. As shown in Figure 4 (B), the connection line is perpendicular to the straight roads. The UWB module on the vehicle communicates with the two RSUs and measures distance to obtain two distance values for positioning.

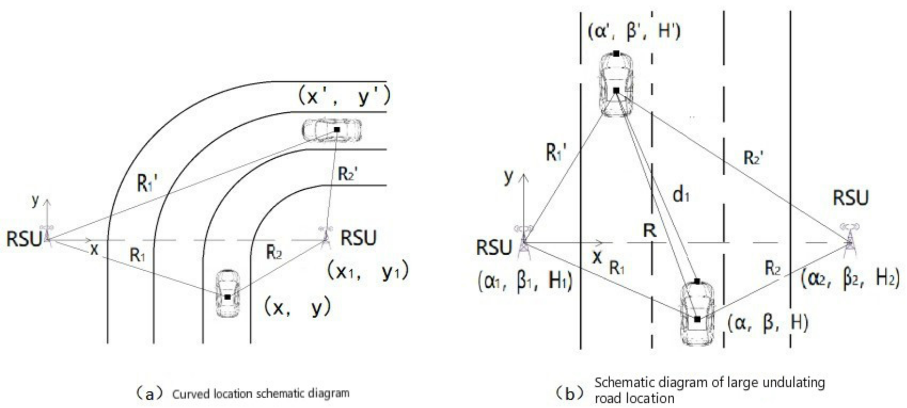

Figure 4. Curved road, large undulating road positioning principle.

2. Optimization of test results based on Kalman filter

Kalman filter is a widely used method[22-23] in vehicle positioning system. Kalman filter can synthesize sensor output value and state estimation value obtained according to prior knowledge, thus obtaining a result closer to the real value, which is a very effective method. On the basis of the above relative positioning method, Kalman filtering is carried out on the obtained position information of surrounding vehicles to further improve positioning accuracy and positioning stability.

The Kalman filter deduces a new state estimatiocn from the recurrence equation according to the acquired measurement data or the estimation value obtained according to the known quantity to realize the recurrence filtering. To process the data by Kalman filter, the filtering state model and observation model need to be established first. Assume that the state model and observation model of Kalman filter are as follows:

$$X_k = F_{k/k-1} X_{k-1} + \Gamma_{k-1} W_{k-1} \quad (6)$$

$$Z_k = H_k X_k + V_k \quad (7)$$

Since the recursive linear minimum variance estimation of Kalman filter can only be realized under the assumption that both the state model and the observation model are linear, the uniform acceleration motion model of the vehicle is tested under smooth straight road conditions.

According to the positioning results of the first two moments, this paper obtains the relative motion speed value of the vehicle, and estimates the relative position of the vehicle at the next moment from this speed. At the same time, the positioning results at the next moment are obtained by combining the measurement values of the positioning system, wherein the results of the first two positioning are directly given according to the observation values. Take the state matrix x k and the state transition matrix f k/k-1 as follows:

$$X_k = \left[x, y, \dot{x}, \dot{y} \right]^T \quad (8)$$

$$F_{k/k-1} = \begin{bmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (9)$$

The observation results given by the positioning system are the relative position coordinates of the surrounding vehicles. In combination with the above error analysis, the relative positioning filter test is carried out on two vehicles running at uniform speed in the adjacent lanes in a certain section of Changsha suburb. According to the filtering result graph, after filtering the positioning result obtained by the positioning method in this paper, the result is closer to the real value, further reducing the positioning error and increasing the positioning stability.

3. Conclusion

This paper analyzes the importance of high precision relative positioning in intelligent driving assistance system, and puts forward a relative positioning method based on vision and V2X aiming at the deficiency of existing relative positioning methods. It is divided into two working conditions of flat straight road surface and curved or fluctuating road surface. The error distribution and maximum error value of relative positioning under the two working conditions are calculated and analyzed. After analysis, the positioning error is controlled within 0.38m of flat straight road surface, within 0.35m of curved and fluctuating road surface, and the positioning stability is further increased after Kalman filtering. The relative positioning method carries out relative position determination by V2X communication ranging and combining vision to obtain road information, greatly reduces roadside unit arrangement, and can meet the requirement of an intelligent driving system on relative positioning accuracy

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