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Testing and Application of Expressway Roadside Perception Method Based on Camera-Radar Fusion

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Abstract. In order to test the performance and application effect of roadside perception method based on camera-radar fusion in the multi-source heterogeneous data environment of expressways, a camera-radar fusion perception algorithm is implemented and deployed in the Yanqing-Chongli intelligent expressway of China. Firstly, a fusion perception and positioning algorithm based on mmWave radar and camera was developed and deployed in the test nodes on the roadside facilities of the expressway. Secondly, the positioning accuracy of the algorithm was tested and analysed. Then the structured data results of the fusion perception algorithm are further analysed and processed to realize the management of target information library. Finally, some practical scenario applications have been proposed based on previous fusion perception results. The results show that the proposed algorithm can achieve lane level positioning and the deployed applications have achieved good results.

Keywords. expressway roadside perception; camera-radar fusion; positioning accuracy; target information library; scenario application

1. Introduction

As an important part of intelligent transportation system, cooperative vehicle infrastructure system (CVIS) adopts advanced wireless communication and a new generation of Internet technologies, to implement dynamic real-time information interaction between vehicle and vehicle, vehicle and infrastructure in all directions, which provides an active vehicle safety control and collaborative road management based on the collection and integration of dynamic traffic information in all time and space. With the application of CVIS, traffic safety could be guaranteed and traffic efficiency could be improved. In recent years, CVIS is increasingly integrated with MEC and V2X technology.

The concept of Multi-Access Edge Computing (MEC) was first introduced in 2014. It was named Mobile Edge Computing at first, which aims to migrate cloud computing platforms from the inside of mobile core network to the edge of mobile access network. Since 2016, the MEC concept has been officially expanded to multi-access edge computing, and the application scenarios have been further extended from mobile cellular networks to other access networks [1]. The basic idea of MEC is to transfer

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computing, storage and business service capabilities to the edge of the network close to the terminal or data source, which aims to deeply integrate the traditional telecommunication network with the Internet business, so that the content and services could be deployed locally and distributedly. The network traffic load can be reduced with MEC, and applications with real-time processing, security and reliability can be built. Vehicle to Everything (V2X) is a new generation of information and communication technology that connects vehicles with everything, where V represents vehicles and X represents any object that interacts information with vehicles. At present, information patterns for V2X interactions include: Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Vehicle to Pedestrian (V2P) and Vehicle to Network (V2N) interactions. The standardization work of V2X has been basically completed and the industry has entered the stage of rapid development.

With the support of the above two technologies (MEC and V2X), great changes have taken place in the construction of supporting roadside facilities in CVIS.

The traditional roadside facilities include cameras, radars, variable information boards, road signs, etc. Cameras are usually used for monitoring and radars are used to measure the speed of vehicles. When traffic violations are detected, the evidence can be captured by a camera. When abnormal conditions occur on the road, the variable information board is used to warn the vehicles behind. This traditional way of deployment of roadside facilities mainly performs monitoring and management. It has certain shortcomings in real-time capture of emergencies because it often requires manual labor and cannot notify vehicles behind in time after an emergency occurs.

In the new CVIS environment, the density of sensors, including cameras and radars can be increased and edge computing terminals, RSUs can be added to the roadside facilities. The edge server can collect a large number of heterogeneous multi-source data and process it directly in a short time, and the result will be broadcast to nearby vehicles by RSU. These data usually have different data formats and encoding formats. After fusion, the system with higher robustness can be obtained, so as to achieve a wider range of applications. However, this kind of application based on the new CVIS environment is seldom studied and realized.

The research relies on Yan-Chong smart expressway in Beijing, China, which was built with a complete MEC-V2X system. It deployed millimeter-wave(mmWave) radars, cameras, edge computing nodes, and RSUs at a high density along the 18km distance expressway. This research mainly includes the following contents: Firstly, we developed a fusion perception and positioning algorithm based on mmWave radar and camera, and deployed it in the test nodes on the roadside facilities of the expressway. Then the structured data results of the fusion perception algorithm are further analysed and processed to realize the management of target information library. Finally, we put forward the specific application based on the data obtained in different expressway scenarios.

The structure of our paper is as follows: In the first section, background of the research is introduced. In the second section, the related research of roadside perception in recent years has been shown. In the third section we introduce the details of the project that our research relies on, which is, the specific terminal deployment of Yan-Chong smart expressway. In the fourth section, we explain the fusion perception algorithm, as well as the testing result during the deployment process of the algorithm. In the fifth section, we introduce a method to manage the target library based on the results of the fusion perception algorithm, and the concrete application is designed in this smart expressway according to different scenarios. Finally, we make a brief summary and prospect of this research.

2. Related Work

Roadside perception based on cameras and radars uses multiple sensors, which belongs to the category of multi-sensor fusion. At present, this kind of perception method is often used in autonomous vehicles. An autonomous vehicle usually equips multiple cameras, mmWave radars, lidar, ultrasonic Radar and other sensors. Compared with the perception of a single sensor, this realization scheme has significant advantages in the perception of complex scenarios such as urban roads, as shown below:

1. Higher system robustness. The measurement results of multi-sensor usually have a certain degree of redundancy. When one sensor breaks and cannot be used, other sensors can usually be supplemented, which improves the robustness of the system.
2. A wider detection range in space. Due to the difference of perception principles and installation locations of sensors, multi-sensor perception can effectively expand the spatial perception range.
3. A wider range detection in time. The synergistic effect of different sensors can effectively improve the detection probability. At certain times, one sensor may detect the targets or events that other sensors miss.
4. Higher confidence. A variety of different sensors can be used to detect the same target, which leads to higher reliability and lower uncertainty.

In recent years, there have been many studies on the fusion perception of single autonomous vehicle. The combined use of mmWave radar and camera has become a classic case of single vehicle perception. Felix Nobis proposed a deep learning-based millimeter-wave radar and image fusion algorithm, and the performance of their fusion network (CRF-Net) is better than the existing pure image network [2]. Wang proposed an improved joint probabilistic data association (JPDA) multi-target tracking algorithm based on camera-radar fusion. The test results show that the target tracking is stable and the fusion result has good accuracy, and the problem of effective target loss is solved [3]. With the popularity and cost reduction of lidar in recent years, many studies have also turned to the fusion of lidar and cameras. The three-dimensional lidar sensor and the two-dimensional color camera provide supplementary information of the scenario and Yuqi Ding fused the two in their research work [4]. Yasin Yeniaydin proposed a lane detection algorithm based on lidar and camera, which significantly improved the accuracy of lane detection [5]. Jaekyum Kim proposed a camera lidar fusion network based on deep learning, and they verified through experiments that the performance of the fusion network is better than traditional sensor fusion methods [6].

As far as roadside fusion perception is concerned, the related research is not as rich as vehicle perception. The following will briefly introduce the research status of roadside fusion perception in recent years.

Lefei Wang proposed a new roadside sensor fusion system [7]. This system can filter out the background target from the radar detection to avoid the wrong calibration and fusion with the camera detection. It can also realize the automatic calibration of the camera and the radar, and reduce the time cost of the system implementation. Experimental results show that their method could quickly realize the automatic acquisition of road sensor information.

Yanjin Fu proposed a camera-radar fusion perception algorithm based on edge computing [8]. YOLOv3 is used to process the camera data, and the DBSCAN clustering method is used to process the radar data. Then joint calibration is used to achieve the spatial synchronization, and the direct update method is used to achieve the time synchronization. In addition, the Munkres algorithm is adopted to correlate the detections of the camera and radar, and the Kalman filter is applied to track the perception results.

Kheireddine Aziz proposed a fusion framework of radar and camera sensors as a fragile road user perception system that can automatically detect, track and classify different targets on the road [9]. The first module of the system performs spatial-temporal alignment on the common plane of detection provided by the radar signal processing and video processing modules. The second module is dedicated to data association for alignment detection. The centralized fusion algorithm takes the currently aligned detection set (location and label) as the input of the two sensors, and uses the Kalman Filter-based Joint Probabilistic Data Association (JPDAF) algorithm to perform multi-target tracking.

The materials and methods section should contain sufficient detail so that all procedures can be repeated. It may be divided into headed subsections if several methods are described.

3. Supported Project

3.1 System Architecture

Our research is based on the Yan-Chong Smart Expressway in Beijing, China. The total length of the smart highway is about 18km. A V2X and MEC integrated management system has been built on the expressway, which is mainly composed of platform, edge and terminal equipment. The system architecture is shown in Figure 1.

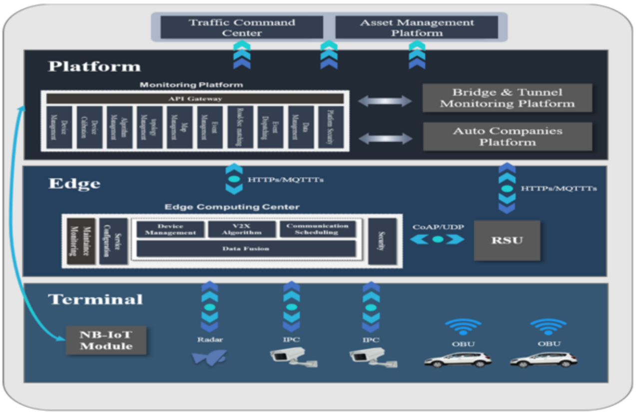

Figure 1. V2X and MEC integrated management system architecture.

The V2X and MEC integrated management platform mainly includes platform host system, network system, network security system and platform software. It could realize equipment management, equipment calibration, algorithm management, topology management, road matching, map management, event management, data management, security protection and other functions. Edge side equipment includes intelligent perception nodes and RSUs. Terminal equipment is mainly composed of high-definition cameras, mmWave radar and on-board terminals.

In this project, the CVIS consists of three subsystems:

1. traffic operation monitoring and management subsystem
2. ramp diverging and merging collision warning subsystem
3. special weather perception and warning subsystem.

Our research mainly focuses on the first two subsystems. The deployment of sensors in different scenarios will affect the subsequent application of fusion perception results, so the terminal deployment plan is described as follows.

3.2 Terminal Deployment Plan

The traffic operation monitoring and control subsystem is composed of intelligent perception nodes, cameras, mmWave radars, guidance screens, RSUs, OBUs and other devices, which are mainly erected on the main road section and tunnel sections.

In the main road section, the erection interval of cameras is 105 meters, mmWave radar is 210 meters, and RSU is 420 meters. Switches are erected every 105 meters and edge fusion perception nodes are erected every 210 meters. The deployment scheme is shown in Figure 2.

In tunnel sections, the erection interval of cameras is 75 meters, mmWave radar is 150 meters, and RSU is 225 meters. Switches and fusion perception nodes are set up every 150 meters. The deployment scheme is shown in Figure 3.

For the ramp diverging and merging warning subsystem in Yan-Chong smart expressway, two fusion perception nodes, including four cameras, four mmWave radars, and one RSU device, are set up at each ramp diverging and merging place. The specific setting position is shown in Figure 4.

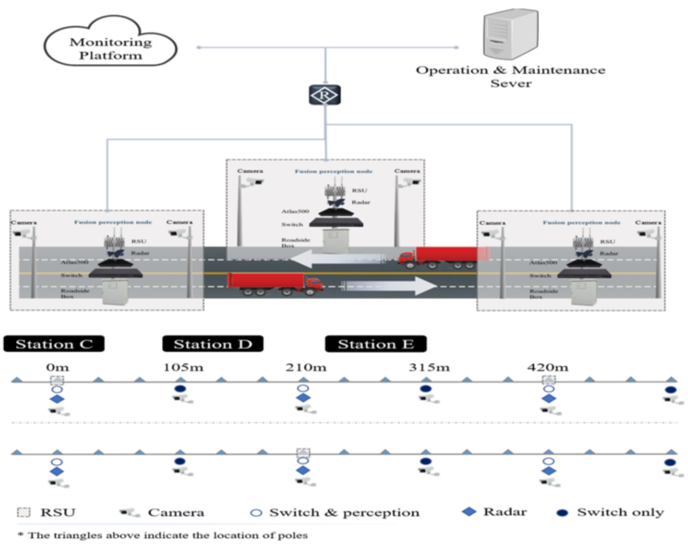

Figure 2. hardware erection of traffic operation monitoring and control subsystem in the main road section

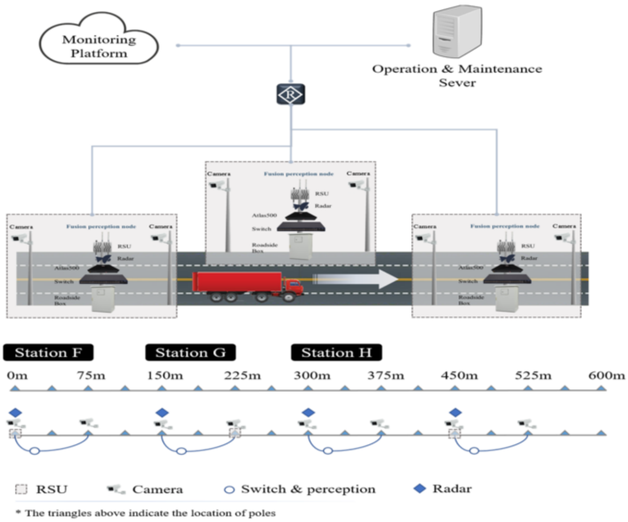

Figure 3. hardware erection of traffic operation monitoring and control subsystem in tunnel section

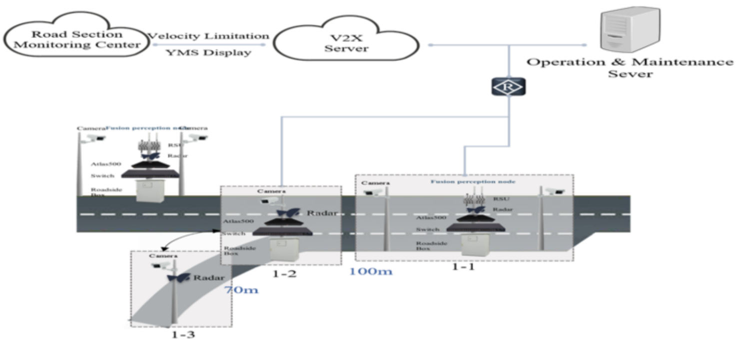

Figure 4. hardware erection of ramp diverging and merging collision warning subsystem

4. Fusion Perception Algorithm and Test

4.1 Fusion Algorithm Flow

The process of fusion perception algorithm that we adopt refers to previous paper [8], and the specific process is shown in Figure 5.

The first step is traffic data collection. The main acquisition sensor of this project is composed of high-definition camera and mmWave radar. The image of the camera is directly pulled through the RTSP protocol for processing. The position accuracy of the radar target detection is lane level in the transverse direction, within 2 meters accuracy in the longitudinal direction. The target detection precision is 80% inside the tunnel and 90% outside the tunnel, and the speed measurement error is 2km/h.

The second step is the pre-processing of camera and radar data. The camera is processed by YOLOv3 to obtain basic information such as vehicle type and position. The radar could detect the target directly, we just need to decode the data from radar according to the datasheet.

The third step is data association. For time synchronization, we chose the direct update method. For spatial synchronization, we calibrated the camera and radar respectively at first, and since the two sensors were installed in similar positions on the expressway, their coordinates could be directly used as the sensor positions. After that, we use Hungarian algorithm to achieve target matching between radar and camera, and then the measurement information from those different sensors is fused to get the fusion result.

The fourth step is target tracking, which tracks those targets after data fusion. The Kalman filter combined with Hungarian algorithm is applied to achieve vehicle target tracking.

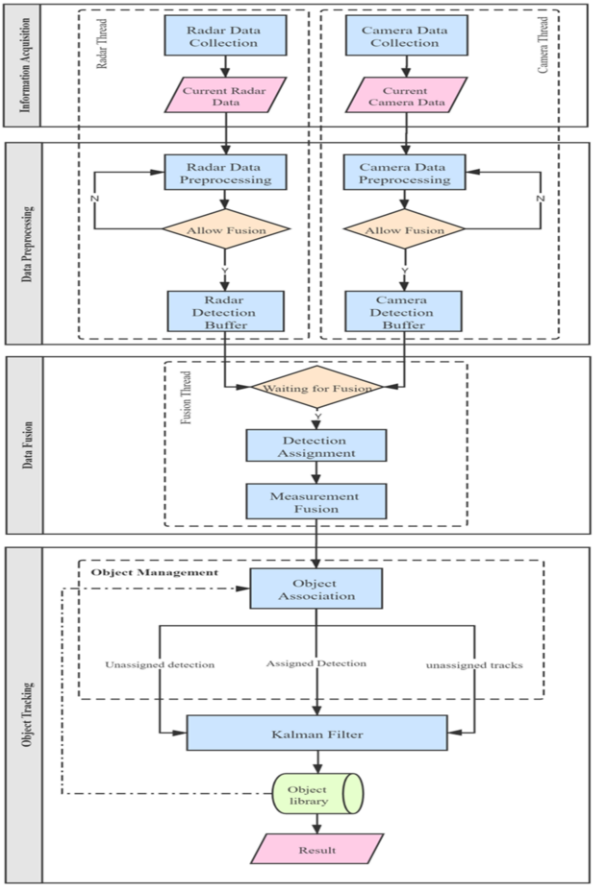

Figure 5. The Flow of Camera-Radar Fusion Algorithm

4.2 Algorithm Deployment

We deployed the algorithm in the test field, and the tasks completed mainly included lane line calibration, sensor calibration and association calibration.

4.2.1 Lane Calibration

Three lanes were used during the test, and the centerline of each lane is used as the reference line. We collected five points on each lane as lane reference. Real - time kinematic (RTK) terminal is used to collect the longitude and latitude information of these reference points, and the data is shown in Table 1.

Table 1. Lane reference points

reference points of Lane 1	reference points of Lane 2	reference points of Lane 3
116.13419242,40.10055302	116.13418117,40.10052924	116.13416993,40.10050547
116.13415134,40.10055536	116.13415168,40.10052298	116.13415203,40.10050460
116.13410659,40.10055173	116.13410802,40.10053484	116.13410947,40.10051796
116.13407706,40.10054824	116.13407979,40.10052695	116.13408258,40.10050603
116.13405154,40.10054476	116.13404952,40.10053014	116.13404758,40.10051585

4.2.2 Camera Calibration

The camera adopts the corner calibration method. The corresponding longitude and latitude is collected based on the obvious corner points within the camera range. We collected the data of 11 corners and got the Homograph matrix for calibration finally, as shown in Figure 6.

```
homography_matrix: !!opencv-matrix
   rows: 3
   cols: 3
   dt: d
   data: [ -1.5486562508997255e-02, -9.8175244531939487e-02,
       4.0100550764958335e+01, -4.4850112894743881e-02,
       -2.8432285549212233e-01, 1.1613407398866761e+02,
       -3.8619288889582039e-04, -2.4482285579768277e-03, 1. ]
```

Figure 6. Camera Calibration Matrix

4.2.3 Joint Calibration

The radar and camera are installed at the same position in the test field, so the relative position error can almost be negligible. The position coordinates of the two sensors are collected as follows:

{lon: 116.13433756, lat: 40.10052730}

4.3 Positioning Accuracy Test

After the calibration, we compare the accurate data collected by hand-held RTK terminal with the data of fusion sensing algorithm to test the positioning accuracy of our algorithm. First, we open the deployed fusion perception algorithm and then a tester will hold the RTK terminal in hand and stay at the respective center of the three lanes for a period of time. In this way, two sets of data can be obtained for comparison. The longitude and latitude information of stable state can be used directly, and the time registration between fusion perception results and the data collected by RTK terminal can be eliminated.

As for RTK terminal, the coordinate points are collected every second. Since the testers stay on each lane for a certain period of time, the beginning 10 data, the middle 10 data, and the last 10 data are respectively intercepted as the reference points for collection, and the average longitude and latitude information is calculated and shown in table 2.

Table 2. RTK data

fixed position data collected by RTK	
Average latitude and longitude coordinates of position 1	pos1_rtk = {"lat":401005367,"lon":1161340724}
Average latitude and longitude coordinates of position 2	pos2_rtk = {"lat":401005391,"lon":1161340830}
Average latitude and longitude coordinates of position 3	pos3_rtk = {"lat":401005195,"lon":1161340993}

As for the fusion perception algorithm, we choose part of the output of the fusion perception algorithm. The average longitude and latitude coordinates of the three fusion perception results after analysis are shown in table 3.

Table 3. Fusion Algorithm data

fixed position data by Fusion Algorithm	
Average latitude and longitude coordinates of position 1	pos1 = {"lat":401005362,"lon":1161340637}
Average latitude and longitude coordinates of position 2	pos2 = {"lat":401005324,"lon":1161340712}
Average latitude and longitude coordinates of position 3	pos3 = {"lat":401005248,"lon":1161340862}

The error of longitude and latitude coordinates between the measurement and the sensor could be obtained by inputting the results above into the distance calculation function, as shown in table 4.

Table 4. Error Distance

Error Distance	
Error Distance in Position 1	0.74206m
Error Distance in Position 2	1.24994m
Error Distance in Position 3	1.26047m
Average Error Distance	1.08416m

Therefore, the positioning accuracy error of the fusion perception algorithm under the calibration is 1.08m, which is less than the general width of the lane between 3.5m, and lane level positioning accuracy can be realized.

5. Fusion Perception Algorithm and Test

5.1 Objects Management

An object management library is created to store and manage the results of fusion perception, which is running in a new process on edge computing node. Data of fusion perception result is shown in Table 5.

Table 5. Fusion Perception Field

	Field Name	Explanation
1	type	Type of perception node
2	msgCnt	ID number of message
3	minOfYear	Minutes from the present year
4	second	Seconds from the present minute
5	fuDevID	ID of perception nodes
6	refPos	Latitude and longitude of fusion perception node
7	objectList	Objects list of fusion perception

The field *objectList* stores the information of all objects, the information fields are shown in Table 6.

Table 6. Object Field

	Field Name	Explanation
1	objectID	ID for objects(This identity is unique)
2	objectType	Type of objects. 1:motor;2:non-motor;3:pedestrain;4:truck; 5:car
3	objectPos	Latitude and longitude
4	speed	vehicle speed with a resolution of 0.02m/s
5	laneID	ID of lane, the left lane is set 1
6	heading	Vehicle heading angle, The heading angle of the vehicle is the angle between the heading direction and the true north direction. The resolution is 0.0125 degrees

The object management library includes the following fields shown in Table 7.

Table 7. Object Library Field

	Field Name	Explanation
1	objectsPreLib	New vehicles will be cached here
2	objectsHistoryLib	Vehicles that have left will be saved here
3	objectsLib	Save the vehicle in motion
4	matchMatrix	match matrix

Each management library stores the object data of fusion perception. The vehicle ID is selected as the unique identifier of each vehicle. The entire management process is as follows:

Step1: Get the object ID from the fusion perception result obtained in the current frame.

Step2: Compare the current ID with the ID in objectsLib to obtain a 0-1 matrix matchMartrix. The place where one corresponding ID exists is marked as 1, otherwise it is recorded as zero.

Step3: Process the target object according to the result corresponding to the matchMartrix, which can be divided into three situations.

1. if the ID of the objectsLib has the same ID in the current frame, update the object information of the corresponding ID in objectsLib.
2. if there is a ID in objectsLib but not in the current frame, this ID will be marked as disappearance. If the disappearance mark accounts for three times, destroy this object and move it into the historical object library.
3. if there is a ID in current frame but not in objectsLib. compare the ID of with the IDs in objectsPreLib. If it is a new ID that has been recorded in objectsPreLib, it will be marked as appearance. If the appearance marker appears three times, the object will be added into objectsLib.

5.2 Scenario Application

After the object management of the structured data obtained from the fusion perception, we further explore the possibility of its application in different scenarios. According to the specific deployment of Yan-Chong expressway, we divide the application scenario into three parts including general road application, merging area application and diversion area application.

5.2.1 General Road Applications

This part includes warning of abnormal vehicle speed warning, congestion degree judgement, and dangerous spacing warning.

5.2.1.1 abnormal speed warning

This application is to warn the cars with abnormal speed on the road. The data related to abnormal vehicle speeds includes three types: overspeed vehicles, low-speed vehicles, and stopped vehicles. According to the priority of the event, the order of processing data is: stopped vehicle prior to the overspeed or low-speed vehicle. The speed limits of Chinese highways include lane limits and types limits. The regulations are as follows:

1. Lane speed limit: the minimum speed must not be less than 60 km/h;. If there are 2 lanes in one direction, the minimum speed of the left lane is 100 km/h; if there are 3 lanes in one direction, the minimum speed of the leftmost lane is 110 km/h, and the minimum speed of the middle lane is 90 km/h.
2. Type speed limit: The maximum speed of high-speed limited small passenger cars shall not exceed 120 km/h, other motor vehicles shall not exceed 100 km/h, and motorcycles shall not exceed 80 km/h.

5.2.1.2 congestion degree judgement

When traffic congestion occurs on the road, the roadside unit monitors the congestion information of the current road section in real time and sends it to the vehicles that may be affected and the monitoring center to realize the real-time monitoring of the traffic flow on the expressway. The fuzzy comprehensive evaluation method divides the congestion state of the sensing node.

1. Establish the judgment object factor set of the highway state $U = [\bar{V}, \bar{T}]$, and use the average traffic flow speed $\bar{V}$ and the average delay $\bar{T}$ to characterize the traffic flow operation state. The average speed and average delay time statistics are performed every fifteen minutes.
2. Establish the result of the judgment object of the expressway state $F = [f_1, f_2, f_3, f_4, f_5]$ which corresponding to five states from unimpeded to congested.
3. Establish a single factor evaluation, and construct a factor mapping from the evaluation object U to the result set F. By calculating the membership function, the membership function values $[R_1, R_2]$ are obtained respectively, where $R_1 = [\mu_1, \mu_2, \mu_3, \mu_4, \mu_5]$, $R_2 = [\rho_1, \rho_2, \rho_3, \rho_4, \rho_5]$.
4. Conduct comprehensive factor evaluation. $B = A * R$, where A is a fuzzy set, which represents the weight of a single factor for comprehensive evaluation; B is a comprehensive evaluation matrix, corresponding to five types of traffic states, and the final result selects the largest in matrix B as the current fusion perception node Traffic status.

5.2.1.3 dangerous spacing warning

For a motorcade running at a certain speed on a highway, when the distance between vehicles is less than a safe value, the front emergency braking is likely to cause the motorcade to rear-end. The coverage range of a single fusion sensing node is about 200 meters and the minimum distance shall not be less than 50 meters. The dangerous spacing detection can be divided into the following steps:

1. Match each vehicle into the corresponding lane according to the map information.
2. Calculate the distance between adjacent vehicles in each lane
3. Analyze each lane separately, and each spacing shall not exceed 50m or 100m.
4. Broadcast the message when there is an exception.

5.2.2. Merging Area Application

Excessive speed difference between vehicles on the main road and the ramp in the merging area may cause accidents. The possible situations are listed below:

1. Vehicle stops on the main road
2. Vehicle overspeed on the main road
3. Excessive Volume on the main road
4. Vehicle stops in the ramp
5. Truck merge

There are two sensing nodes arranged in the merging area, which respectively sense traffic incidents on the main road and ramp. The warning messages are processed individually. The application process for the main road is shown in Figure 7 and the application process for the ramp is shown in Figure 8.

Figure 7. Main Road Safety Warning Proceeding

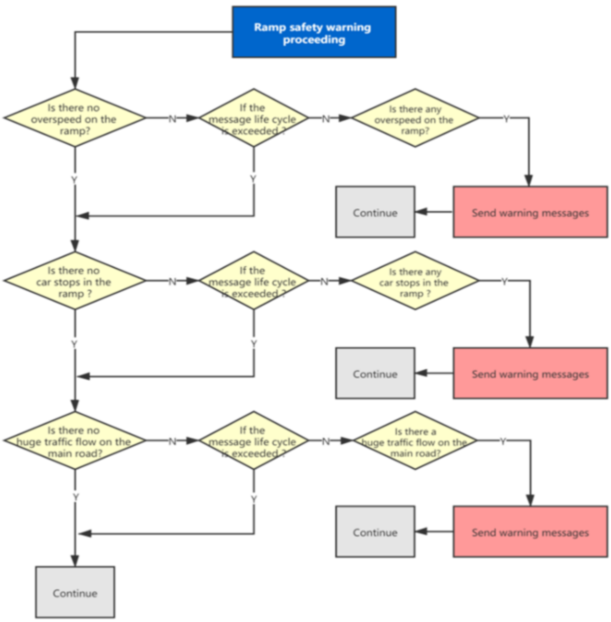

Figure 8. Ramp Safety Warning Proceeding

5.2.3. Diverging Area Application

The possible dangerous situations in the diverging area are listed below:

1. Continuous lane change of vehicles
2. Vehicle stops on the road
3. Vehicle reverses on the road

The sensing nodes in the diversion area are implemented at the following crossings, and the warning process is shown in Figure 9.

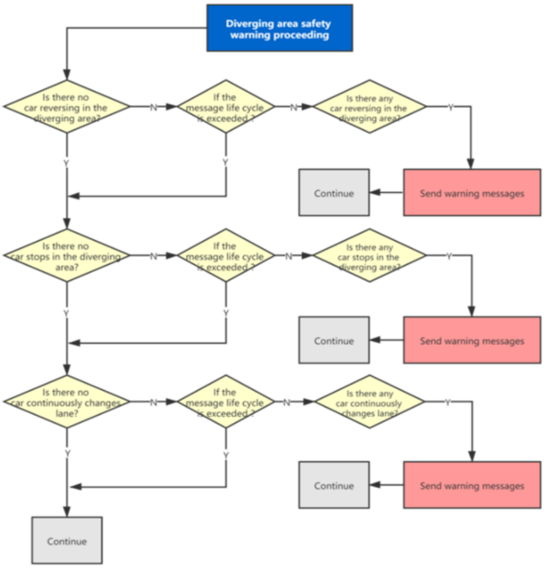

Figure 9. Diverging Area Safety Warning Proceeding

5.3 Application Testing

The proposed applications were implemented at the test spots on the real way. The test methods and results are shown in Table 8.

Table 8. Application Test and Result

Scenarios	Application	Test Method	Result
General Road Application Test (Assuming that the roadside fusion sensing node is set up in the normal section of the highway, the main road lane number from the inside to the outside is 1, 2, 3)	Stopped Vehicle Warning	The tester stops at Lane 1, Lane 2 and Lane 3 respectively. Open the stopped vehicle warning module to observe whether the stopped vehicle warning information is issued.	SUCCEED
	Overspeed Vehicle Warning	The tester drives the vehicle at high speed in Lane 1, Lane 2 and Lane 3 respectively, open the speeding vehicle warning module and observe whether the warning information of speeding vehicles is issued.	SUCCEED
	Low Speed Vehicle Warning	The tester drives the vehicle at low speed in Lane 1, Lane 2 and Lane 3 respectively. Open the low speed vehicle warning module, and observe whether the low speed vehicle warning information is issued.	SUCCEED
	Congestion Degree Judgement	Due to the limited number of test vehicles, we simulate the multi vehicle road condition data. Three vehicles, five vehicles and ten vehicles are simulated in the test section with different speed distribution and lane distribution, and the accuracy of congestion judgment is tested based on the simulation data.	SUCCEED
	Dangerous Vehicle Distance Warning	Tester 1 and tester 2 drive the front and rear vehicles respectively, and keep the following distance within 10 meters (far less than the minimum distance allowed by the expressway). Open the dangerous distance warning module to observe whether the dangerous distance warning information is sent correctly.	SUCCEED
Merging Area Application Test (There is only one fusion sensing node in the test field, and there is no standard ramp. In the test process, lane 3 is regarded as ramp, lane 1 and lane 2 are regarded as main roads.)	Vehicle Stop on the Main Road	The tester 1 drives the vehicle to stop at the main road side (Lane 2), and the tester 2 drives the vehicle from the ramp (Lane 3). Open the main road vehicle stop warning module, and observe whether the warning information is sent out correctly.	SUCCEED
	Vehicle Overspeed on the Main Road	The tester 1 drives the vehicle at high speed in the main road lane (Lane 2), and the tester 2 drives the vehicle on the ramp (Lane 3). Open the main road vehicle overspeed module in the scene application algorithm, and observe whether the warning message is sent out correctly.	SUCCEED
	Excessive Volume on the Main Road	Assuming that there are more than 7 vehicles on the main road at the same time, it is considered that the traffic volume on the main road is large in the current period. Under the simulation traffic volume, open the warning module of excessive traffic volume to observe whether the warning information is sent out correctly.	SUCCEED
	Vehicle Stop in Ramp Acceleration Area	The tester 1 drives the vehicle on the ramp (Lane 3) and stops, turns on the ramp area illegal parking module and observes whether the warning message is sent out correctly.	SUCCEED
	Truck Merge Warning	This test is omitted because there is no truck, and the result is related to the classification part of the camera perception algorithm.	——
Diverging Area Application Test	Continuous Lane Change Warning	The test vehicle directly presses the line to change lanes according to the requirements, tests two groups of data respectively, from Lane1 ->Lane2->Lane3 , from Lane3 -> Lane2->Lane1.Open the continuous lane change warning module to observe whether the information is sent out correctly.	SUCCEED
	Vehicle Stop on the Road	The driver stops in front of the diversion area. Open the stopped vehicle warning module in the scene application of diversion area, and observe whether the warning information is sent correctly.	SUCCEED
	Vehicle Reverse on the Road	The driver drives the test vehicle to reverse in Lane 1 and Lane 2 in front of the diversion area, and opens the reversing vehicle warning module to observe whether the reverse warning information is sent out correctly.	SUCCEED

6 Summary

In this paper, relying on the infrastructure of Yanqing-Chongli intelligent expressway, we implement a camera-radar fusion perception algorithm and deploy it in the test site. The results show that the algorithm can achieve lane level positioning. We managed the object library, and proposed some applications in different scenarios based on previous fusion perception results. The applications have been deployed in tes site and achieved good results.

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