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AN APPROACH OF HIGH DEFINITION MAP INFORMATION INTERACTION

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ABSTRACT:

High definition (HD) maps play a very important role in the realization of autonomous driving technology. It assists self-driving vehicles to efficiently and safely complete a series of driving decisions and route planning by virtue of having most of the accurate and reliable prior information in the road environment. With the continuous change of technology, there are higher requirements for the accuracy, richness and freshness of the information stored in the HD map, so as to assist the practical application of automatic driving technology. However, current research related to HD maps mainly focuses on static information in the road environment. Since there is a large amount of complex, variable and uncertain dynamic information in the road environment, it can be used as prior knowledge for self-driving to make better decisions. Therefore, the research focus of this paper is on the dynamic information. We propose to use HD map as an information system - high definition map information system (HDMIS) - to assist autonomous driving vehicles. We design the specific content of dynamic information in the HDMIS, and develop an information interaction approach based on the vehicle end of the self-driving car and the HDMIS cloud as the interactive subject of dynamic information. In the experiment, we design and build three types of specific traffic scenarios on the simulation platform, and verify the effectiveness of the interaction approach by using the database to perform information interaction between different ports. The results show that our interaction approach can meet the storage and release of dynamic information by HDMIS to a certain extent, and can provide a large amount of dynamic information for autonomous vehicles to help them complete subsequent driving decisions and planning.

1. INTRODUCTION

High definition (HD) maps play a key role in autonomous vehicles for reliable localization and navigation. A HD map should consist of static and dynamic data layers, involving features of road environments, such as lane line, moving objects and related semantic information, of which the spatial resolution should be centimetric-level (Liu et al., 2020). Recently, numerous research on HD maps mainly focus on detecting and collecting information that is insensitive to time on roads, which is used to data update for local road environments. However, there is a lack of studies focusing on dealing with time-sensitive data in road environments - the information that change dynamically in real-time, with characteristics of richness, freshness, complexity, and uncertainty. Therefore, it is a big challenge for HD maps, as a platform, to manage, manipulate and store such data in an effective way.

In this paper, we follow the current common logical model of HD map data (Liu et al., 2019), with a focus on dynamic information interaction. Figure 1 shows the dynamic information level of the HD map. We propose a HD map information interaction approach, which can be applied to specific driving scenarios. This interaction ultimately supports the mission and motion planning of the autonomous vehicle (Ulbrich et al., 2017). The method specifies the content of information interaction between the vehicle side and the cloud side in different scenarios in the HD map information system, and the vehicle side obtains real-time information of road environments via the HD map platform in time to support self-driving car to make more efficient and safe driving decisions. Figure 2 gives a general description of the information interaction. Then, we test the proposed information interaction approach for three simulated types of common scenarios by designing a concrete HD map scenario environment on the RoadRunner platform, where database technology is used for the information interaction between the vehicles and the cloud. Furthermore, the effectiveness of the proposed information interaction approach is verified by analyzing the results of the behavioral decisions made by the vehicle after making adjustments in the virtual simulation scenario. It also demonstrates the capability of HD map as a higher dimensional information sensor in the field of autonomous driving.

The contributions made by this study are threefold: Firstly, it defines the classification and data exchange format of the dynamic information with timeliness in road environments. Secondly, focusing on the time-sensitive data in road environments, an approach of information interaction in different scenarios is proposed. Lastly, this study highlights high definition maps as an essential technological foundation in the field of autonomous driving, which can guarantee more efficient decision-making and safer driving when traveling with autonomous vehicles.

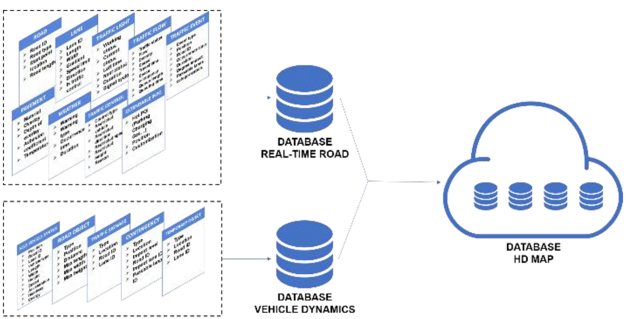

Figure 1. Dynamic information of HD maps. The dynamic information includes two parts - road real-time information and vehicle dynamic information. The metadata of each type of data

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is in a uniform format: name, field, field attributes, and description. Using a relational database, the information of each part is stored in a table of the corresponding database and finally integrated into the master database of HD map data

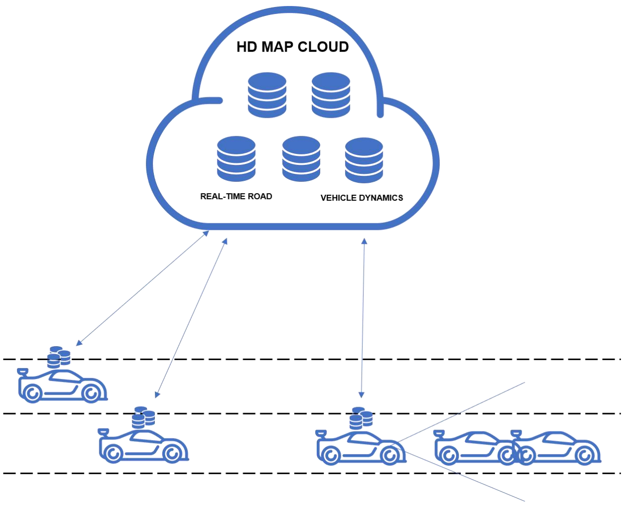

Figure 2. Information interaction between vehicles and the cloud and the content of the two types of information need to interact in a specific scenario.

2. HIGH DEFINITION MAP INFORMATION SYSTEM

2.1 HD Map Information Framework

The high definition (HD) map concept was first introduced in the Mercedes-Benz research in 2010 and later contributed to the Bertha Drive Project (Ziegler et al., 2014, Bao et al., 2023) in 2013. Until now, there are several HD maps structures proposed by map providers, autonomous vehicle companies and academic research groups. In this paper, we propose the concept of HD map information system (HDMIS) as shown in Figure3. Liu et al (2019) proposed the intelligent high-precision map that is applied to this study. In our HDMIS, HD map consists of two parts. One part is a static HD map layer, and the other part is a dynamic HD map layer. The static HD map layer is mainly based on static road feature information, including high-precision data information such as road network (road location, road boundary, etc.) and lane network (lane lines, lane geometric information, etc.). The dynamic HD map layer is mainly based on complex and changeable dynamic information that affects vehicle traffic in the road traffic environment (traffic control, road obstacles, etc.).

After the effective combination of the two parts of the map information, the physical environment within a certain range of the road is mapped to the HDMIS in detail, providing strong support for self-driving vehicles to make decisions (e.g., lane changes, acceleration and deceleration) and planning (e.g., real-time route planning).

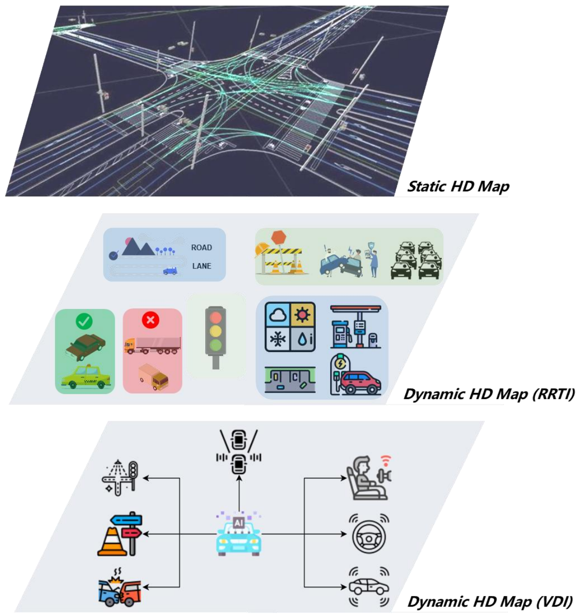

Figure 3. High-definition map information system

2.2 Dynamic Information

For the dynamic high-definition map layer, the data information on it is mainly time-sensitive information that affects traffic travel in the road environment. Dynamic information is divided into two categories: one is road real-time information (RRTI), from the perspective of the road, covering a large amount of dynamic real-time information within the road range that may affect normal traffic travel; The other type is vehicle dynamic information (VDI). From the perspective of unmanned vehicles, it includes the affected or potentially affected road traffic information perceived by each unmanned vehicle while the vehicle is driving on the road.

RRTI includes five types of sub-information: traffic signal information, traffic flow information, traffic control information, traffic event information, and road surface object information. VDI includes four types of sub-information: vehicle status information, temporary traffic sign information, temporary road object information, and temporary event information.

2.3 Information Interaction Modes

In the HDMIS, information collection terminals are mainly unmanned vehicle terminals and the HDMIS cloud (including local clouds). The information interaction between the two types of data ports can combine 3 different information interaction modes: The vehicle-to-cloud information interaction mode, the cloud-to-vehicle information interaction mode, and the vehicle-to-vehicle information interaction mode.

1) The vehicle-to-cloud information interaction model. The unmanned vehicle perceives the surrounding environment of the vehicle in real time through the self-vehicle perception system, converting the perceived large amount of environmental information into the data content corresponding to the VDI after preprocessing by the on-board computing unit, and then performing data inter-action with the cloud in a timely manner.

2) The cloud-to-vehicle information interaction mode. A large amount of RRTI is stored in the cloud and updated in real time. According to the own needs of each unmanned vehicle,

information interaction is performed in a timely manner to provide the road information required by the vehicle.

3) The vehicle-to-vehicle information interaction mode. The information sensed by unmanned vehicles can be directly interacted through the communication between vehicles, and some VDI can be directly requested to interact with specific vehicles without going through the cloud.

3. METHOD

This section mainly introduces the content of the dynamic information interaction approach for HD maps proposed by us.

3.1 Information Interaction Approach

In the HDMIS, the basic unit that carries dynamic details is the lane (or road) to which the current dynamic information belongs. Take the traffic signal information in RRTI as an example. Signal lights generally control the right of way in all directions at intersection, and we refine this right of way to each lane. The specific method is to give each lane the passage information stipulated by the current traffic lights, which can be directly used by the driverless car machine without the need to judge the right of way by observing the color of the signal lights at road intersections, which greatly improves the efficiency of vehicle decision-making. The following is a detailed introduction to the interaction approach in each type of information interaction mode.

1) Vehicle-to-Cloud Information Interaction Mode
In this approach, the information exchanged from the vehicle terminal to the cloud is mainly the VDI, including vehicle status information, temporary traffic sign information, and temporary event information. Figure 4 shows the vehicle-to-cloud interaction mode. The type of information that each vehicle interacts with depends mainly on the information it actually perceives during operating.

Vehicle status information is to collect and share the information of the current vehicle itself. The interactive information includes the current location of the vehicle, vehicle speed, head orientation, vehicle acceleration, vehicle size, etc.
Temporary traffic sign information means that in some special cases, roads need to temporarily place traffic signs to guide cars to change their original driving behavior. The interaction information includes signboard location, traffic signboard category, etc.

Temporary event information refers to some sudden traffic events that make the original planned route of the vehicle unable to pass smoothly at present. The interaction information includes the location where the event occurred, the type of the event, and the degree of impact of the event.

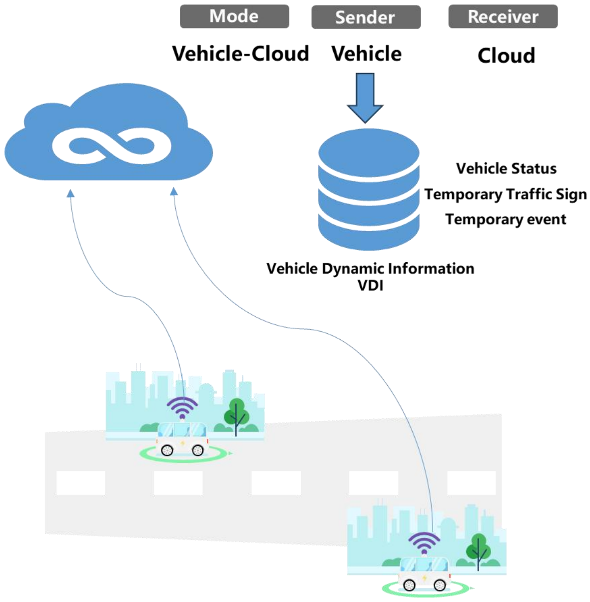

Figure 4. Vehicle-Cloud Information Interaction Mode

2) Cloud-to-Vehicle Information Interaction Mode
In this approach, the information exchanged from the cloud to the vehicle is mainly the RRTI as shown in Figure5, including traffic signal light information, traffic flow information, traffic control information, traffic event information, and road surface object information.

Traffic signal light information refers to the right-of-way information indicated by the traffic lights at the intersection, and at the same time, the right-of-way information is directly specific to each lane. The interactive information includes the current state of the signal light, the remaining time, the next state, the duration of the next state, and the signal cycle.

Traffic flow information is a description of the macro-traffic flow in the traffic road network. This part of the information is mainly used to assist unmanned vehicles in planning. The specific interactive information includes traffic status, lane flow, lane density, lane speed, lane passing time, queue length, etc.

Traffic control information refers to roads or lanes, information in the case of temporary control of roads or some lanes due to the needs of traffic control policies. The specific interactive information includes control types, restricted vehicles, restricted passing directions, restricted passing heights, restricted passing speeds, and restricted passing weights.

Traffic event information refers to the information that some temporary traffic events cause some roads or lanes to be temporarily unavailable for normal traffic. The content of the interactive information mainly includes the location where the event occurred, the time of occurrence, the expected duration, the degree of impact, the passable lane, and the category of the event.

Road surface object information mainly refers to the information of special covering objects on the road surface under special circumstances. The interactive information includes covering type, covering depth, current road surface adhesion coefficient, road surface temperature, etc.

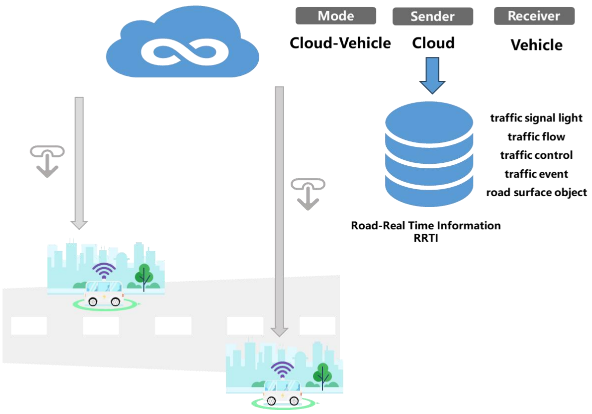

Figure 5. Cloud-Vehicle Information Interaction Mode

3) Vehicle-to-Vehicle Information Interaction Mode
In this approach, the information exchanged from the vehicle end to the vehicle end is mainly the VDI as shown in Figure6, including vehicle status information and temporary road object information. Temporary traffic sign information and temporary event information can also be requested if required. Because this information will be converted into the information content corresponding to the RRTI after other vehicles interact with the cloud.

The vehicle status information refers to the current status information of the own vehicle, which is consistent with the information interaction in the vehicle-to-cloud interaction mode. Temporary road object information refers to the information of dynamic or static objects that appear around the current driverless vehicle. Dynamic objects mainly include moving objects such as other vehicles, pedestrians, and non-motorized vehicles. Static objects mainly refer to unknown and infrequently moving objects that hinder the passage of vehicles. The interactive information content includes object classification, object location, object geometric size, distance to the object, etc.

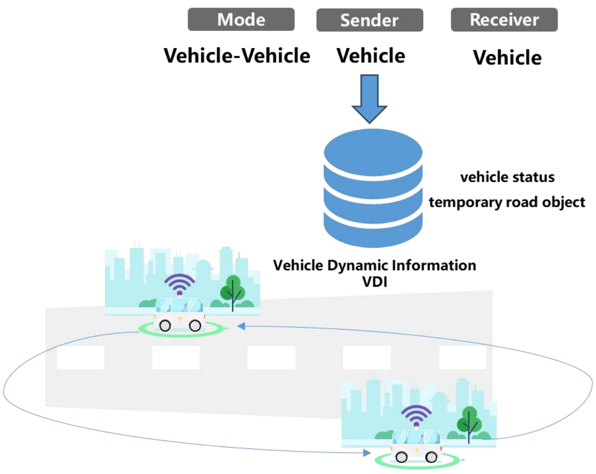

Figure 6. Vehicle-Vehicle Information Interaction Mode

3.2 Interaction Scenario

In this study, three common driving scenarios are designed, namely the ghost probe scene, the traffic control scene, and the scene where unknown static objects appear in the middle of the lane.

1) Ghost Probe Scene
At a road intersection, a pedestrian does not obey the traffic rules and chose to run a red light to cross the road. The current traffic status of the road is that some lanes can turn left or right, and other lanes are prohibited from going straight. Due to the size of the vehicle on the lane where straight driving is prohibited, the vehicle turning left behind does not notice the pedestrian. However, the left-turning vehicle can obtain the pedestrian information (dynamic object information in the temporary road surface object information) through the vehicle-vehicle interaction mode, so as to adjust the driving decision in time, such as slowing down in advance.

2) Traffic Control Scene
Due to special reasons, a traffic sign indicating that the lane is temporarily closed is placed on a certain lane. However, the information that the lane is temporarily controlled has not been updated in the HDMIS. An unmanned vehicle driving in this lane senses the information of the temporary traffic sign and exchanges this information in time through the vehicle-cloud interaction mode. The cloud receives information from the vehicle interaction, updates it to the traffic control information in a timely manner, and sends it to other vehicles that will pass through this lane, assisting the vehicle to re-plan the route in advance.

3) Unknown Object Appears Scene
During the normal driving of an unmanned vehicle, it suddenly perceives a stationary object in the center of the front lane, which will affect the normal passage of the vehicle, and the current vehicle has to make a decision to change lanes. At the same time, this information can be transmitted to the rear vehicles in the same lane in time through the vehicle-vehicle interaction mode, so that they can make decisions about changing lanes in advance.

4. EXPERIMENT

This section presents the experimental validation part of the proposed information interaction approach. Considering the complexity and safety of the traffic scene in the real world, this research experiment is carried out in the joint simulation platform of Matlab and RoadRunner. The interaction information involved is unified in the relational database, and the interaction process is carried out between the vehicle database and the cloud database.

4.1 Ghost Probe Scenario Verification

Design the ghost probe scene in RoadRunner according to the scene design requirements, and extract information from the designed scene. The ghost probe scenario is shown in Figure 7. The extracted information includes road information, lane information, traffic signal information, vehicle status information, and temporary road surface object information. This scenario involves information exchange between two vehicle terminal databases.

For the vehicle in the lane but currently at rest, the vehicle-end database information includes vehicle status information and temporary road object information. Vehicles in the left-turn lane and accelerating through the intersection have vehicle status information in the vehicle database. By implementing the vehicle-vehicle information interaction mode, the temporary object information (pedestrian) is received in time in the database of the left-turning vehicle.

Figure 7. Ghost Probe Scenario

4.2 Traffic Control Scenario Verification

In RoadRunner, build a traffic control scene according to the scene design requirements, and extract the information in the scene. The traffic control scenario is shown in Figure 8. The information includes road information, lane information, temporary traffic sign information and traffic control information. The vehicle-end database contains vehicle status information and temporary traffic sign information. The cloud database contains detailed road information, lane information and traffic control information before updating.

First, by implementing the vehicle-cloud information interaction mode, the vehicle-end database exchanges vehicle status information and temporary traffic sign information with the cloud database. Then the cloud updates the information of the temporary traffic signs to the traffic control information. At this time, the traffic control information of the lane is updated, and the cloud database can publish this information to the vehicle-end databases of other vehicles using the current lane.

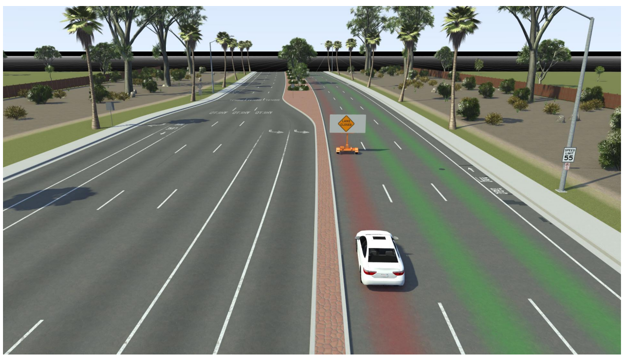

Figure 8. Traffic Control Scenario

4.3 Unknown Object Appears Scenario Verification

Similarly, the scene is built on the RoadRunner platform according to the established scene design requirements, and the information in the scene is extracted and stored in the databases of the two vehicle terminals. The unknown object appears scenario is shown in Figure 9. The information includes road information, lane information, and temporary road object information.

In the scene, the vehicle that first perceives a large stationary trash can in the center of the lane will implement the vehicle-to-vehicle information interaction mode with vehicles driving in the same lane in time. That is, the database of vehicle 1 performs information interaction with the database of vehicle 2.

Figure 9. Unknown Object Appears Scenario

4.4 RESULT

In the simulation platform, the ghost probe scene, the traffic control scene and the scene of unknown static objects appearing in the middle of the road are built. After the scenes are built, the information involved in different scenes is extracted according to the content in the dynamic information, and stored in the database where each information terminal is located. Then use the proposed information interaction approach in the information interaction mode to interact with the data between the databases to test the interaction method we proposed. The results of information interaction show that in three different scenarios, the content of the final interactive information can meet the expectations. However, the research in this paper only involves the information interaction process in a small area in a specific scenario and with a small number of terminals. The effectiveness of the information interaction process under the large-scale scale in the actual situation remains to be further studied.

5. CONCLUSION

This paper proposed the concept of the high-definition map information system. In this system, the data logic structure of HD map consists of two layers, namely static high-precision map layer and dynamic high-precision map layer. We have further divided the information on the dynamic high-precision map layer, which consists of real-time road information (RRTI) and vehicle dynamic information (VDI). On the basis of defining the logical structure of HD map data, the data information of different layers is also divided and defined in detail for use in information interaction. In the HDMIS, there are mainly two types of terminals for information interaction: unmanned vehicle terminals and the HDMIS cloud. The combination of the 2 types of ports forms 3 different information interaction modes (vehicle-to-cloud, cloud-to-vehicle, vehicle-to-vehicle information interaction modes), and each mode has its own information interaction approach to meet the information exchange between different ports. Finally, we validate the proposed interaction approach by designing ghost probe scenarios, traffic control scenarios and scenarios where unknown static objects appear in the middle of the road. However, there are still limitations in this research. The interaction data used in the experiment is carried out in an ideal simulation environment, and the amount of interaction data is small, which is not enough to reflect the huge traffic scene in the physical world. In addition, the applicability of the interaction approach is completely considered in the case of pure unmanned vehicles, and the applicability of this approach in the case of human-machine mixed driving has not been proved, which also needs to be considered in future research. In general, this paper improves the research on dynamic information interaction of high-definition map to a certain extent and provides the approach of information interaction for the application of automatic driving technology supported by HD map in the future.

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