Intelligent Transportation and Autonomous Vehicles

Introduction to Pro. Liu Jiangnan

- Chinese geodesist and educator;
- **President** of Duke Kunshan University from 2012.
- **Academician** of Chinese Academy of Engineering since 1999;
- Former president of Wuhan University from 2003 to 2008;
- Have developed the first GPS satellite positioning data processing system in China;
- Participating the design of National High Precision GPS Network;

Organizer:

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Department of Natural Resources of ZheJiang Province (Administration of Surveying Mapping And Geoinformation)

United Nations World Geospatial Information Congress • Deqing

Progress and Thinking on Intelligent High Precision Maps

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Wuhan University

2018.11

Foreword

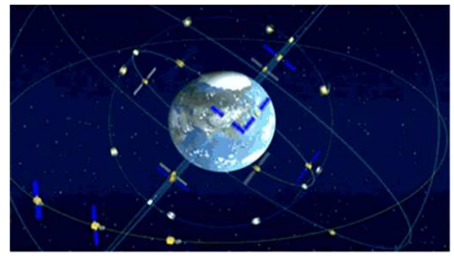
Historic evolution of using maps in the car

Contents

1. Background and demands

1.1 Advancement of GNSS technology

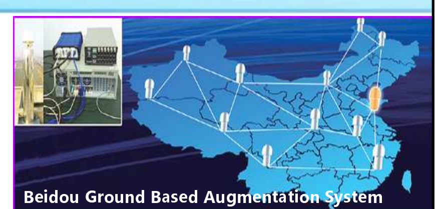
- BeiDou Navigation Satellite System(BDS)
  - China is building BDS-3, and will provide services including SAR(Search and Rescue) and SMS(Short message service) worldwide around 2020
  - The 18th,19th BeiDou-3 satellite was launched on Nov.19
  - BDS is about to serve Belt and Road this year



1. Background and demands

1.1 Advancement of GNSS technology

- BeiDou Ground-based Augmentation System(BDGBAS)
  - Enhance the BeiDou/GNSS system by broadcasting satellite signal error corrections
  - BDS-3 will be able to provide real-time precise position and augment service for navigation with meter to centimeter level accuracy to china



- Accurate dynamic positioning + High precision maps

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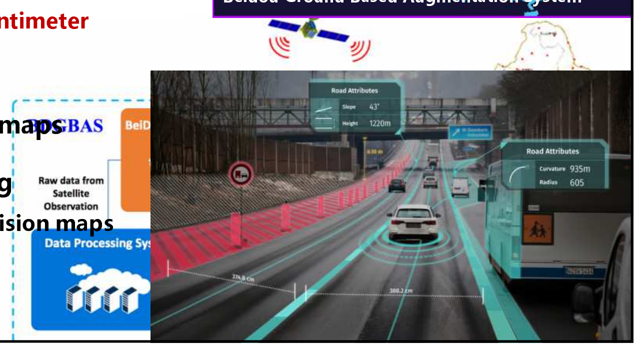
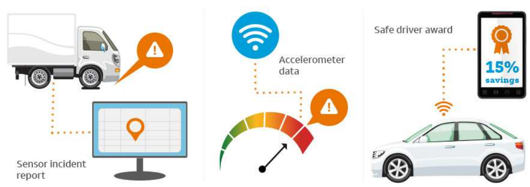
  navigation needs for Autonomous Driving
  - connect precise GNSS technology with high precision maps to meet the diverse needs in the intelligent era

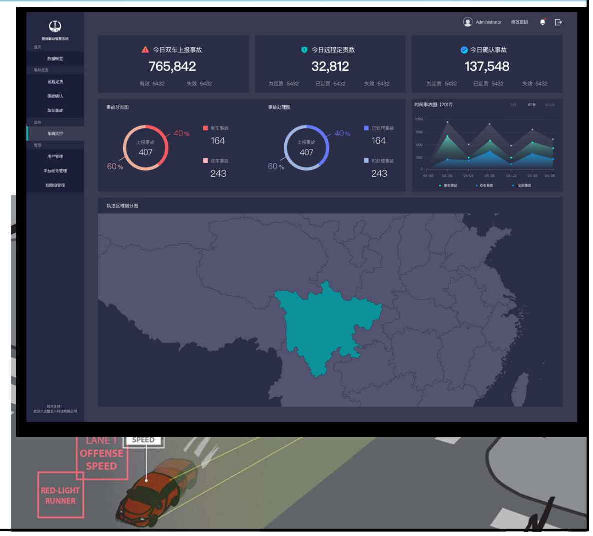


1. Background and demand

1.2 Accurate and intelligent trends of traffic management

- Growing needs of Traffic Management and Transportation Planning require precision not only road level , but also lane level with meter level
  - Navigation for reversible lanes and HOV Lanes
  - Lane supervision in traffic violation
  - Online determination of responsibility and loss for vehicle accidents
  - Usage Based Insurance(UBI)





1. Background and demand

1.2 Accurate and intelligent trends of traffic management

- "Internet + Intelligent Transportation" Plan
  - Human-centered
  - Comprehensively promote online integration and sharing of transportation resources, such as transportation infrastructure, transportation tools, transportation system, etc.
  - safe and convenient mobility, green, intelligent, ubiquitous service
  - provide location service with precise time and position in wide area

1. Background and demand

1.3 Intelligent and Connected Vehicles and Autonomous Driving

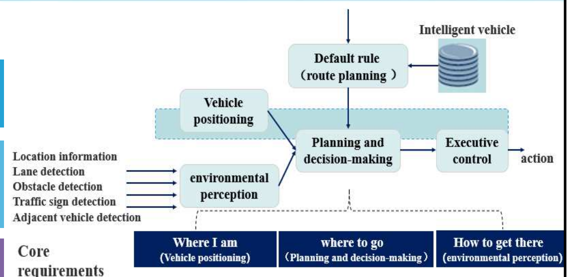
- **Related national policies**

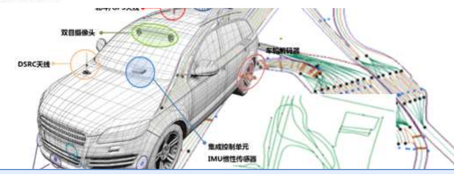
The United States will develop intelligent Internet of Vehicles as the key work content for the development of intelligent transportation systems
The federal self-driving vehicles policy has been published in 2016

The government actively promotes cross-sectoral synergy and promotes the implementation of intelligent networked automotive projects.
It is planned to allow automated vehicles in restricted areas in 2020 and form a fully self-driving car market target in Japan by 2025

"Innovative development strategy for Intelligent vehicles" put forward the idea to build a national basic map system for vehicle with unified standards, and to establish and improve 3D geo-information system, further more to provide real-time dynamic map data service

- **Safety requirements of Autonomous Driving**
  - The subject of live environmental Perception changed from human to machine
  - Driving system puts high demands on safety and stability and requires a high match between accurate real-time positioning and high-precision road map





Intelligent High-Precision Map(IHPM) is the carrier of high-precision environment perception and the foundation of real-time road control for autonomous/unmanned driving

Contents

2. Compared with traditional map

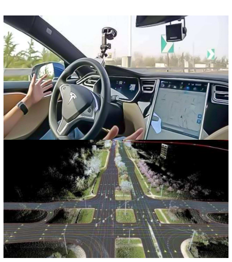
2.1 Definition and classification of Intelligent High-Precision Map(IPHM)

- **IPHM is an intelligent map that meet the following constraints:**
  - has absolute accuracy of the coordinates better than 0.1m
  - contains two kinds of information, one is static information such as shape of roads and lanes, traffic constraints and surrounding traffic environment, another is semi-dynamic or dynamic information such as real-time traffic and obstacles
  - able to process information with collaboration of cloud computing and the IoT
  - able to serve multiple areas such as delicacy management of intelligent transportation , Autonomous Driving and Robot navigation etc.

2. Compared with traditional map

2.1 Definition and classification of Intelligent High-precision Maps(IPHM)

- **According to Application Scenarios , it can be divided into four categories : high precision maps for vehicle, for control center, for robots, and for cloud**



Autonomous Driving

Traffic control and insurance application

Robots

Cloud

2. Compared with traditional map

2.2 Theory development of high-precision map for vehicles

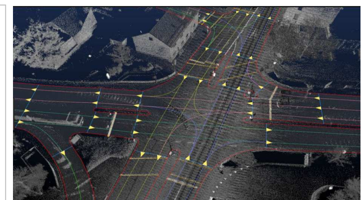
- **Information load and expression(What is the information?)**

Traditional Maps

- Information is divided into direct information and indirect information
  - ✓ Direct information is simply reflected by graphics and symbols
  - ✓ Indirect information depends on user's own understanding and spatial data mining in post-processing
- The map information is updated manually

Intelligent High Precision Maps

- Being more refined, dynamic and real-time, they put more emphasis on data mining and automatic acquisition of indirect information
- User's understanding of the objective world is enhanced from map spatial perception to dynamic cognition
- The map information is updated synchronously while map is being used



2. Compared with traditional map

2.2 Theory development of high-precision map for vehicles

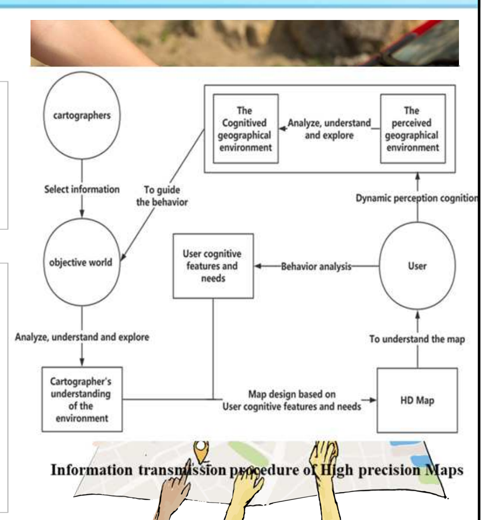
- **Information transmission (Where is the information from?)**

Traditional Maps

- As the spatial models of the objective world, they are the cartographer's understanding of the objective world within certain norms
- Information transmission is a one-way process from cartographer to user

Intelligent High Precision Maps

- An extension of traditional maps which can be understood by machine
- Collaborations between professional cartographers and crowdsourcing data
- Users no longer just receive data, but also participate in map production
- Users' cognition and personalized needs will affect final presentation of the map model, to realize the self-adaptation between the maps and users' requirements



Information transmission procedure of High precision Maps

2. Compared with traditional map

2.2 Theory development of high-precision map for vehicles

- **The use of information (How to use the information?)**

Traditional Maps

- The assisted decision-making ability (like planning) of maps is based on users' understanding of the environment
- Human is the subject in the process of map using. Based on their own visual perception and logical thinking ability, users rely on geo-information carried by graphically expressed maps to complete specific task

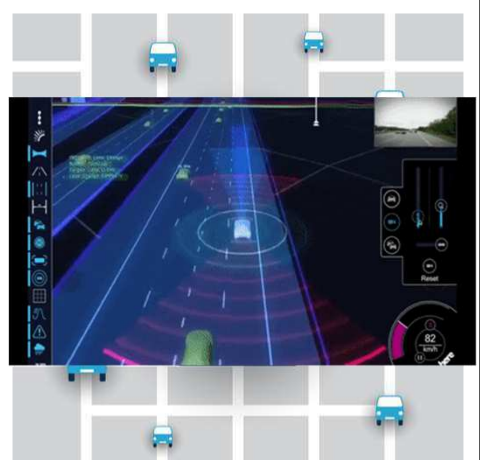
2. Compared with traditional map

2.2 Theory development of high-precision map for vehicles

- **The use of information (How to use the information?)**

Intelligent High Precision Maps

- The machine becomes another subject in the process of map using, The usage is "human-machine-map" interacting with each other
- Quantitative and digital high-precision maps provide highly detailed and dynamic environmental information
- The live map with real-time perception must participate in the decision-making and real-time control of driving, and be able to self-learning, self-adaptation and self-evaluation

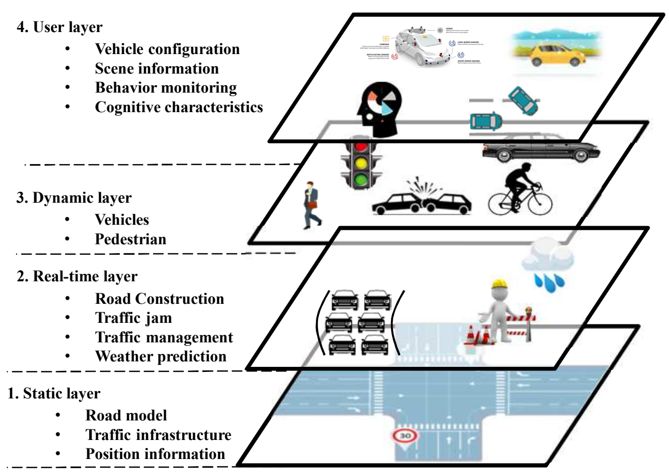


Contents

3. Main elements and layers

3.1 Layers for Intelligent High-precision Maps

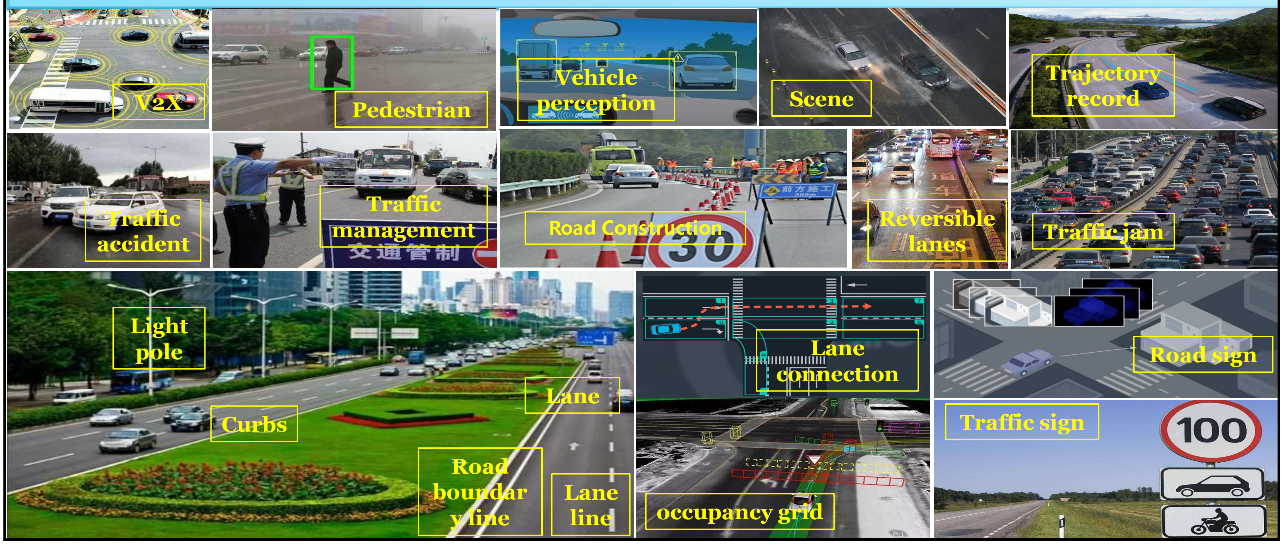
- **Data model**
  - Accurately reflect road environment
  - Achieve multi-scale calibration and high speed access
  - Meet spatial indexing requirements for Positioning, path planning and navigation
- **Layers**
  - Static layer: road/ physical and geometric characteristics of lanes/ infrastructure
  - Real-time layer: real-time traffic and obstacles
  - Dynamic layer: autonomous sensing data /V2X data
  - User layer: Driving task/ Driving behavior/ vehicle configuration



Reference layers of High-precision road navigation map

3. Main elements and layers

3.2 Examples of representative elements



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4. Outlook of technologies and standards

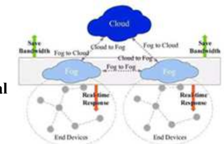
4.1 Several technical problems that need to be solved

Data collection and updating

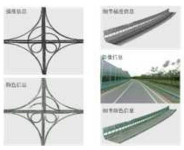
- Centralized professional collection
- Crowdsourcing
- Integration of professional collection and crowdsourcing

Computing Pattern

- Cloud computing
- Edge calculation (cloud and terminal collaboration)

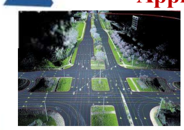


Map production and data processing



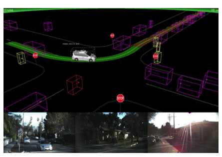
- Multi-semantic segmentation
- Computer vision
- Geometric rendering and topology

Application and usage



- Lane level map matching
- Map-assisted perception and position
- planning and obstacle avoidance

Dynamic data interaction



- Machine vision and target detection
- Multi-source sensor collaboration
- V2X

Autonomous intelligent control

- Accurate match between traffic signs and dynamic position of vehicles
- Real-time driving control through information in Internet of Vehicle
- Environmental and behavioral monitoring
- Driving behavior and driving control

4. Outlook of technologies and standards

4.2 Standards development

International standards

- ISO TC204/WG3—Database construction and data exchange standards for intelligent traffic maps
- OpenDRIVE (standardize the logical road description to facilitate the data exchange between different driving simulators)——OpenDRIVE® V 1.4 Format Specification, Revision H
- ADASIS(Define a interface specifications)——ADASIS v1，ADASIS v2，ADASIS v3
- ETSI——ETSI TR 102 863 V1.1.1 (2011-06)
- NDS Steering Committee put HD map on standardization agenda in 2013 by installing dedicated Working Group 3,then in 2017 NDS standard is ready for 2020 autonomous cars
- Open AutoDrive Forum is the cross-domain platform driving standardizations in the area of autonomous driving
- DMP (Dynamic Map Planning Co., Ltd.)——Study the methodologies of developing and maintaining high-precision 3D map data for Automated Driving

Standards in China

- Lead by Wuhan University—— "Data Specifications of Road High-precision Electronic Navigation Map"
- Lead by Beijing University of Civil Engineering and Architecture—— "Production Technology Specifications of Road High-precision Electronic Navigation Map"
- China ITS Industry Alliance(C-ITS) —— "Digital Map for Intelligent Vehicle Data Model & Exchange Format Specification"
- CAICV HD MAP WG—— 3 subjects: "Research on Automated Driving Map Standard System"(Lead by NavInfo)；" Research on Map deflection and Communication between mapping management departments"(Lead by Amap)；"Research on Autopilot Map Technology and Application Roadmap" (Lead by Wuhan KOTEI Informatics Co., Ltd.)
- Baidu—— Apollo OpenDrive specifcations

- 2018-2019： Ministry of Natural Resources （National Administration of Surveying, Mapping and Geoinformation of China）entrusts Wuhan University, Tongji University, Beijing University of Civil Engineering and Architecture, etc. to set standard related to Surveying, Mapping and Geoinformation Industry, and release the draft of "Data Specifications of Road High-precision Electronic Navigation Map "

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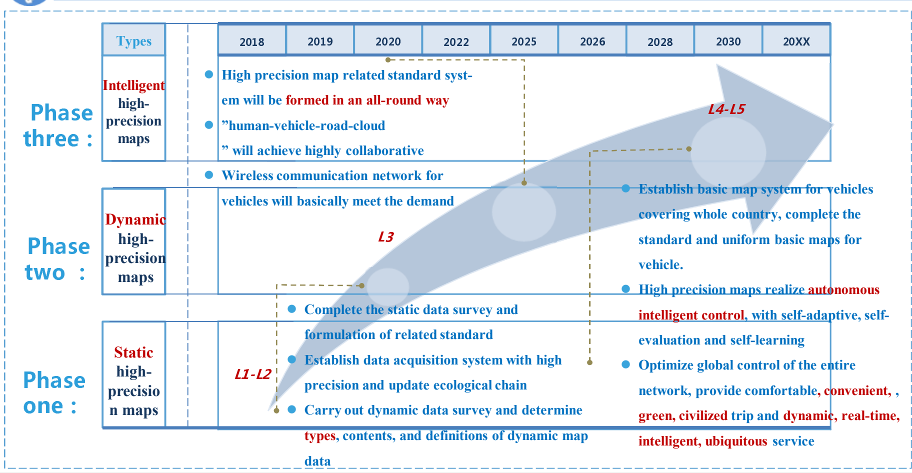
4. Outlook of technologies and standards

4.3 Roadmap

Roadmap of Intelligent high-precision maps

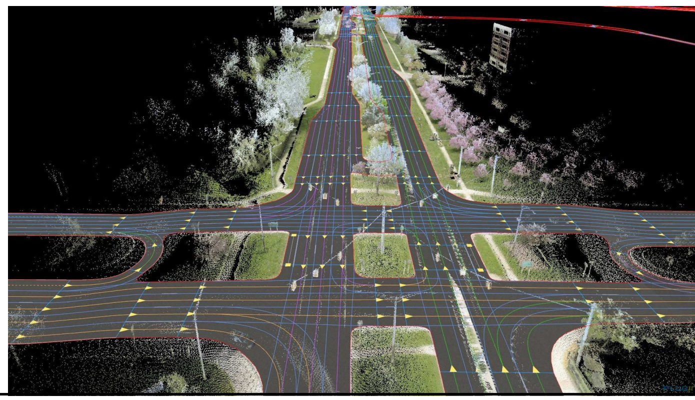


- "The intelligent vehicle innovation and development strategy" released by the national development and reform commission of China specifies the national intelligent vehicle innovation and development strategy: the framework of road network facilities, regulations and standards for standard intelligent vehicles will be basically formed by 2020, and be fully formed by 2025, by that time , "human-vehicle-road-cloud" could be highly coordinated.
- The European Union plans to develop intelligent transport from the two aspects of Internet road environmental resource aggregation and intelligent network vehicles, and aims to achieve that goal by 2050.
- Japan conducted a static data survey of autonomous driving in 2015; Conduct dynamic data research in 2016, and establish dynamic map platform to discuss dynamic map data use cases and element contents. Japan will achieve full coverage of high-precision maps by 2020

Contents

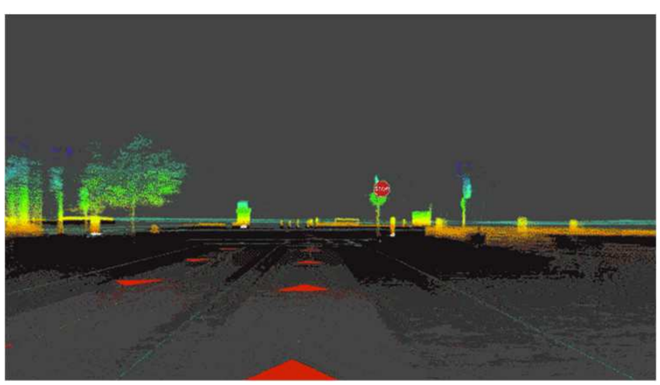
5. Summary and thoughts

- IHPM are indispensable infrastructures for intelligent connected vehicles. Their database can be established and updated dynamically, according to different demands and rules



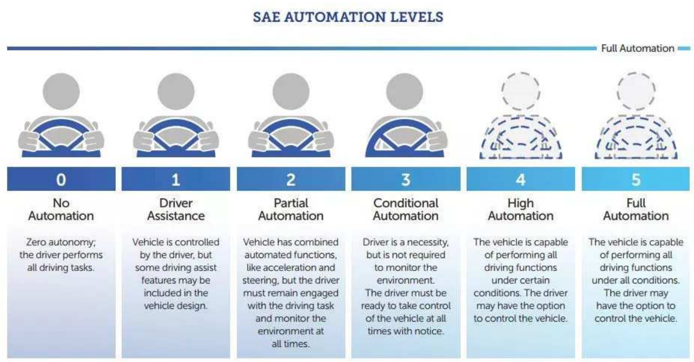
5. Summary and thoughts

- In IHPM, lane lines, 3D coordinates of traffic signs and related parameters (such as, turning radius , gradient), have driving control capability. They are the ultimate control basis while the environmental perception system such as vision or radar fails



5. Summary and thoughts

- **Standards for IHPM are driven by technologies and demands. Since safety requirements are extremely demanding, many standards need to be set simultaneously with laws**

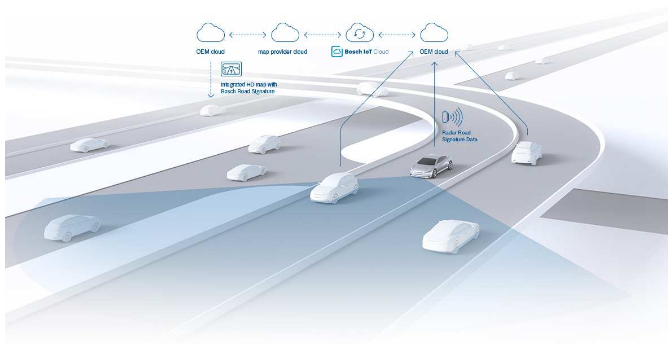


5. Summary and thoughts

- **Crowdsourcing will be a necessary data source to ensure real-time in IHPM. Ensuring data availability, reliability, readability, determining data validity and filtering, and the data interaction priority as well as data delay rules are key points and major difficulties**

5. Summary and thoughts

- **Based on environmental perception and map matching technologies, IHPM have the ability to control Autonomous Driving with specifications such as traffic rules and map data constraints, which traditional maps can not do**



5. Summary and thoughts

- **IHPM are helpful to achieve efficient mobility with high quality, thus the vision of "Mobility-as-a-service" can be realized**

4. Outlook of technologies and standards

4.1 Several technical problems that need to be solved

Data collection	How to reduce high costs of professional collection according to high data update rates?	Integration professional collection with crowdsourcing
Map production	How to reduce costs of computing resource under the condition of big data(point cloud, image, location, etc.) ?	Artificial intelligence is a new approach
Data interaction	How to build real-world environments with dynamic real-time data ?	collaborative awareness of Machine vision and V2X
Computing pattern	How to avoid data backlog due to limited computing power of the cloud platform?	co-processing between Cloud and terminal ends
Applications	How to avoid dynamic obstacles quickly? And how to promote active security information from cloud platform in advance and how can users obtain it?	assistive environmental perception /positioning/planning/control
Intelligent control	How to implement real-time and high precision perception for traffic signs that are used to aid autonomous intelligent driving?	Autonomous intelligent control with self-learning, self-adaptation and self-evaluation