Development of ICV and Smart Mobility in China

Keqiang Li
Professor of School of Vehicle and Mobility, Tsinghua University
Chief Scientist, China National Innovation Center for Intelligent and Connected Vehicles
Chairman of Expert Committee, CAICV (China Industry Innovation Alliance for ICV)
CONTENTS

- Background
- ICV Solution and Innovative Development Paradigm in China
- ICV Solution Supports to Establish Smart Mobility
The ICV integrates Autonomous Vehicle and Connected Vehicle, which brings out New Product, New Paradigm, and New Ecosystem.

**Connected Vehicle**
V2V, V2I, V2P, V2N, real-time communication

**Autonomous Vehicle**
Keep a safe distance from other vehicles and objects by using sensing technology
Two Major Features that Distinguish ICV from Conventional Vehicles

**Interdisciplinary and Cross-industry Integration**

Unlike conventional vehicle, which is a mechatronic product, ICV requires the fusion of mechatronics and ICT. This underlines the industrial integration of automotive, transportation infrastructure, information and communications infrastructure (including 4G/5G, map and positioning, data platforms), etc.

**Significance of Regional and Social Properties**

The regional and social properties of ICV are weighing much more than the conventional vehicle. The operation of ICV requires the support of telecommunications, maps, and data, which are under security monitoring due to national security sensitivity. Each country has its standards, regulations and, legislations regarding this. Therefore Localization Factor exists in the development and application of ICV.

Main countries in the world are exploring technical roadmap and industrial development paradigm
Issues of ‘Single-agent Intelligent Vehicle’ Development

Paradigm One
Incremental Way from Driver Assistance to Intelligent driving

Since mass production is the top priority of the OEMs that adopted this paradigm, the existing and conventional H/S architectures, which hardly meet the ever-growing requirements of autonomous driving, are heavily relied on.

Paradigm Two
One-shot Way that Focuses on High-level Vehicle Intelligence

The radicalness of this paradigm brings along many concerns, such as unvalidated and unproven vehicle safety and reliability. Costs and mass production capabilities are also constraints.
CONTENTS

- Background
- ICV Solution and Innovative Development Paradigm in China
- ICV Solution Supports to Establish Smart Mobility
Actively Promote the Policies and Regulations of ICV

To establish Cross-sector Coordination Process & Top-level Design

- The Ministry of Industry and Information Technology launched **ICV Development Action Plan**
- The Development and Reform Commission issued **ICV Innovative Development Strategies**
- The Ministry of Transport strengthens **Product Application and Pilot Demonstration**
- The Ministry of Natural Resources expands **Market of Map and Position Applications**

**The Regulations of ICV**

**The Roadmap for ICV**

**ICV Closed Field Test Base**

**Enterprises with Qualifications**
The Necessity for a Localized Solution for ICV in China

No experience of successful application of ICV or certainly proven paradigm exists anywhere in the world. The localized solution of ICV innovation and development in China shall be planned according to the need for cutting-edge technologies and industry development and the specific conditions of China.

Neither of the two Paradigms of ‘Single-agent Intelligent Vehicle’ Development is suitable for China’s specific industrial conditions.

**Incremental Paradigm of vehicle intelligent level improvement**
- Our gaps in automotive electronics, control, and actuation would be continuously widened following this paradigm, resulting in "Hollowness" to our core technologies in the automotive industry.

**Radical Paradigm that focuses on high vehicle intelligence levels**
- Without the first-mover advantage in this paradigm, we could end up "strangled" by the west due to critical disadvantages on core technologies, especially in high precision sensors, high-performance central processors, computing platform and toolchains of development and test, etc.,

**Reasons of the necessity for a Localized Solution of ICV in China:**
1. The communication, map, and data used during ICV operations have localization properties that cannot be ignored. Security has to be uniformly governed by the nation. Therefore, a simple copy of foreign technologies would not be plausible.
2. There is no successful experience of ICV development worldwide due to the need for industrial integrations and cooperation. Moreover, innovations are induced by the nature of ICV, the integration of cutting-edge ICT and automotive system technology, and integration technology of the new generation.
New Products with Localization Properties are Required for ICV Development

Definition of Localized ICV Solution

1. Comply with Chinese Infrastructure Standards
   Including standards of road infrastructure, map data, V2X communication, and transportation, etc.

2. Comply with Chinese Connected-Operation Standards
   Including standards of ICV access, supervision of connected operation, information security, etc.

3. Comply with new standardized Architecture of Automotive Products in China
   Including standards of intelligent terminal, communications system, cloud platform, gateways, ADAS, ADS, etc.

The paradigm of China’s Localized ICV Solution

Through architecting localized solution of ICV Cyber-Physical System with the considerations of the combined characteristics of automation and connection, realizing China’s ICV Complex, which is the embodiment of “five fundamental platforms,” underlining the concept of “Human-Vehicle-Road-Cloud.”
ICV is a typical application of CPS in the automotive transportation system of systems.

ICV is a **typical complex CPS** that deeply integrates automotive, transportation, and ICT system of systems.

**ICV CPS**
- **Big Data Computation Based on Real Data**
- Safety, energy-saving, and efficient mobility ecology-oriented coordination/collaboration application (cloud)
- Digitalization of physical space - intelligent data processing and basic database (cloud)
- Standardized Interconnection System
- High Speed & Low Latency Communication
- Standardized Interconnection System
- Physical Space

To meet the complex requirements of interdisciplinary, cross-industrial development and tackle the challenges brought by regional properties, it is imperative to construct a state-of-the-art ICV CPS.
2. Deep Fusion Between Intelligence and Connection Development

China was the first country to classify the levels of intelligence and connection fusion; the technology roadmap is under continuous revision and improvement.

In 2016, the levels of intelligence and connection were proposed alongside the release of “The Technical Roadmap of ICVs,” we were the first country to define the three levels of connectedness, aka connection-assisted information interaction, connection-enabled cooperated perception, and connection-enabled cooperated decision-making and control - an innovative concept and path for industrial development.

We have further revised and improved the milestone implementation plan of vehicle intelligence and connected classification and their industrialization, further exploring the technical route of localized ICV solution.

<table>
<thead>
<tr>
<th>Connected Level</th>
<th>Name</th>
<th>Definition</th>
<th>Typical information</th>
<th>Transmission needs</th>
<th>Typical scenes</th>
<th>Vehicle control body</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Connected Auxiliary</td>
<td>Acquire auxiliary information such as navigation and upload data such as a vehicle running and driver’s operations, based on the vehicle-road and vehicle-background communications.</td>
<td>Maps, traffic flow, traffic signs, fuel consumption, mileage, etc.</td>
<td>Low requirements for transmission timeliness and reliability.</td>
<td>Traffic information reminder, vehicle-mounted information service, weather information reminder, emergency call service, etc.</td>
<td>Human</td>
</tr>
<tr>
<td></td>
<td>Information Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Connected Collaborative</td>
<td>Acquire real-time traffic environment information surrounding the vehicle based on vehicle-vehicle, vehicle-road, vehicle-human, vehicle-background communications, and integrate it with the perceptual information of vehicle-mounted sensors as the input of auto-vehicle’s decision and control system.</td>
<td>Digital information such as locations of surrounding vehicles/pedestrians/non-motor vehicles, signal light phase, road early warning, etc.</td>
<td>High requirements for transmission timeliness and reliability.</td>
<td>Early warning for wet and slippery roads, traffic accidents, and emergency braking, giving way to special vehicles, etc.</td>
<td>Human or system</td>
</tr>
<tr>
<td></td>
<td>Perception</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Connected Collaborative</td>
<td>Acquire the surrounding traffic environment information and vehicle decision information based on vehicle-vehicle, vehicle-road, vehicle-cloud communications; integrate with the information of traffic participants such as vehicle-vehicle and vehicle-road; and achieve intelligent collaboration, thus realizing the collaborative decision and control between traffic participants.</td>
<td>Collaborative perception, decision, and control information among vehicle-vehicle, vehicle-road, and vehicle-cloud.</td>
<td>Highest requirements for transmission timeliness and reliability.</td>
<td>Guiding running speed, vehicle spacing, lane selection, collaborative formation, passing through intersections, ramp confluence, etc.</td>
<td>Human or system</td>
</tr>
<tr>
<td></td>
<td>Decision and Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Deep Fusion between Intelligence and Connection Development

The intelligent and connection fusion development roadmap is being well recognized by many countries.

Many countries are working on an AD technical roadmap based on connection communication technology.

<table>
<thead>
<tr>
<th>Roadmap</th>
<th>Region</th>
<th>Organization</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected Automated Driving Roadmap</td>
<td>EU</td>
<td>European Road Transport Research Advisory Council (ERTRAC)-EU</td>
<td>2019</td>
</tr>
<tr>
<td>STRIA Roadmap on Connected and Automated Road Transport</td>
<td>EU</td>
<td>Strategic Transport Research &amp; Innovation Agenda (STRIA) -EU</td>
<td>2019</td>
</tr>
<tr>
<td>Roadmap for the deployment of automated driving in the European Union</td>
<td>EU</td>
<td>European Automobile Manufacturers Association (ACEA)</td>
<td>2019</td>
</tr>
<tr>
<td>UK Connected and Automated Mobility Roadmap to 2030</td>
<td>UK</td>
<td>Zenzic</td>
<td>2019</td>
</tr>
<tr>
<td>Public-Private ITS Initiative Roadmaps</td>
<td>Japan</td>
<td>Cabinet Office</td>
<td>2019</td>
</tr>
</tbody>
</table>

In 2019, ERTRAC announced *Connected Automated Driving Roadmap*, proposed the development roadmap of network-connected automated driving—ISAD.

In the new version roadmap, ERTRAC stressed collaborated interconnection, increased network-connected AD contents, and explicated Infrastructure Support Levels for Automated Driving—ISAD.
3. Construct Five Base Platforms, Build up New Ecosystem

Industrial Chain of Conventional Automotive Electronics

- **Tier 1**: OEM
- **Tier 2**: Central Cloud, Edge Cloud
- **Tier 1.5**: Processor, Heterogeneous Technology
- **Tier 2**: New Crossover Technologies
- **Core System**: Basic Software Architecture, AI Application, Hardware Acceleration

Industrial Chain of Automated Driving Electronics

- **Tier 1**: OEM
- **Tier 1.5**: AD-OS
- **Tier 2**: Chip, Core, ARM, IP
- **Tier 1.5**: Basic Functions, Heterogeneous Distributed Hardware Architecture
- **Base Computing Platform**: CICV, ICT, OEM, Tier 1, Map, CC

- **Central Cloud**, **Edge Cloud**, **Data Sharing**, **Processor**, **Basic Software Architecture**, **AI Application**, **HD Map**, **Cybersecurity**, **State Governance**, **New Crossover Technologies**

- **Output**: Computing Platform, Base Computing Platform
ICV Development Requires for the Five Base Platforms Imperatively *(New-Form Components)*

- **Base Cloud Control Platform**
  - Standardized Connection
  - Driving Monitor
  - V2X and Roadside Communication
  - Environmental Data Monitoring

- **Base Dynamic HD Map Platform**
  - V2X and HD Map
  - Driving Environment Data

- **Base Intelligent Terminal Platform**
  - Data Fusion and Subpackaging
  - Real-Time Environment Data
  - Vehicle Security and Protection

- **Base Computing Platform**
  - Over-the-horizon Perception and Decision-making
  - Plan and Decision-making
  - Security Protection

- **Base Cybersecurity Platform**
  - Cloud Security Supervision
  - Communication and Encryption
  - Onboard Security and Protection
  - Testing and Certification Capabilities

- **HD Base Map Platform**
  - Corporates: State, Security and Protection
  - Testing and Certification Capabilities
Based on the wide Tier 2 industrial chain and by integrating the basic technology of computing platform company with 3rd party application development platform, automated driving providers, Tier 1, and OEMs to build their upper-level application, demo, and validation environment, and thus formulate the ecosystem of computing platform supply chain.
CONTENTS

- Background
- Localized ICV Solution and Innovative Development Paradigm in China
- ICV Solution Supports to Establish Smart Mobility
China is willing to contribute more to the fight against climate change, as it aims to bring carbon emissions to a peak by 2030 and achieve carbon neutrality by 2060 with more aggressive policies and measures.

—— Chinese President Xi Jinping

“Technology Roadmap for Energy Saving and New Energy Vehicles 2.0”

proposed:

• **2028**: Achieve Peak Carbon Emission in Automotive Industry, fulfill the national commitment of Carbon Emission Reduction

• **2035**: Reduce Overall Carbon Emission more than 20% of Peak Value

China Automotive Industry will approach zero carbon emission in 2050, achieve carbon neutrality by 2060.
ICV Cyber-physical System CPS2.0 includes: ICV development and design CPS, ICV manufacturing CPS, ICV on-board CPS, ICV operation and management CPS, and low-carbon development for Holistic Lifecycle Phases of Automotive Industry and stakeholders.

CPS 2.0 Architecture Prompts Low-carbon Holistic Vehicle Lifecycle

CPS2.0 clarifies reference architecture targeting different service clients and the corresponding ICV lifecycle phase, prompts the low-carbon vehicle industry in intelligent manufacturing, green manufacturing, traffic optimization, and supports carbon neutrality.
The ICV Solution Supports to Establish Future Low-carbon Mobility Service

【Passenger Vehicle】 Energize shared mobility by intelligent and connected technology, support future mobility development, and accelerate decarbonization by shared vehicles. Autonomous driving tests with human involvement are widely deployed in China; the commercialized operation has been stimulated in some cities.

Beijing, Guangzhou, and Cangzhou approved to provide and charge for Robo-Taxi services in specific areas.
Compared to passenger vehicles, commercial vehicles produce higher carbon emissions. Localized ICV Solution achieves commercial vehicle platooning by vehicle-connected technology, reduces carbon emission significantly, and accelerates low-carbon development in the automotive industry.

May 2019, a large-scale public test of commercial vehicle platooning function was tested for validation of “ICV Testing methods and requirement for autonomous driving functions——Part 3: Platooning function.”

Dec 2019, Beijing Chongli Highway, L4 autonomous driving based on the C-V2X vehicle infrastructure cooperative technology and platooning function test, was demonstrated in an enclosed two-way, four-lane road.
As an important realization scenario in the restricted area, autonomous commuter buses have attracted extensive attention from OEMs, Tier 1s, ICT, and start-ups both at home and abroad. Many cross-border products have emerged, which represent one of the more active self-driving applications in recent years.
Localized ICV Solution accelerates a new MAAS (Mobility as a service) generation including multi-mode of transportation, shared mobility, electric vehicle, and self-driving. The next generation of autonomous driving mobile services will create a multi-traffic mode sharing intelligent travel service solution and propel the automotive industry’s transformation.

Dongfeng: Sharing-VAN2.0

- The separation of the electric chassis from the cockpit is achieved, and different cabins can be replaced according to the immediate needs of the manned load.
- Provide a full range of high-quality automotive products and travel services multi-traffic mode solution and explore the next generation of public mobile travel services new model.
The ICV Solution Supports to Establish Future Low-carbon Mobility Service

【Smart City】ICV prompts integration development of the vehicle, smart transportation, and smart city; combines passenger flow, logistics, energy flow, and information flow; achieves connectivity between vehicle and city, transportation, energy; increases city operational efficiency; and saves energy and reduces emission.

Area 1: include Stadium 1 and 2 mainly for demonstration capabilities

Area 2: include Stadium 3/4/5/6/7 mainly for functional demonstration of future city

Area 3: include Stadium 8/9/10 mainly for services

DongFeng Sharing-City
The ICV Solution Supports to Establish Future Low-carbon Mobility Service

Future Smart Mobility Ecosystem based on ICV with New Generation AI

- Satellite Communications
- Roadbase Communications
- Cloud Control Intelligence
- Swarm Intelligence
- Big Data Driven Swarm Decision-making
- Human-Vehicle-Road Interaction Recognition
- Urban Road Smart Driving
- All-Element Connected Perception
- Hybrid Intelligence
- Unstructured Road Smart Driving
- Highway Smart Driving
- Human-Vehicle-Road Collaborated Control
Thank You for Your Attention!