Analysis on Key Issues in the Development Process of Intelligent & Connected Vehicle

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Abstract. In order to get an overall understanding of the development of ICV (Intelligent & Connected Vehicle), this paper predicts the overall development trend of ICV from the perspective of intelligence and interconnection, establishes the corresponding development curve situation chart, and systematically sorts out the corresponding key issues in the different stages of the development process of intelligence and interconnection, so as to provide reference for the research focus of the various stages of ICV.

Keywords: ICV; Intelligence; Interconnection; Integration.

1. Introduction

The development of ICV will bring new impetus for the development of technology-intensive industries such as automobiles, communications, electronics, and the Internet, and will also become a key means to solve social problems such as environment, energy, congestion, and security. As the ultimate form of automobile products, ICV has become the commanding height of the future development strategy of the industry that countries all over the world compete to seize [1]. The reconstruction and transformation of the innovation chain, value chain and ecological chain under the pattern of automobile industry has become an irreversible trend.

As the largest automobile market in the world, China has a profound foundation and strategic advantages in information technology, industrial base, market space and mechanism construction. However, at the same time, due to different culture and consumption habits of Chinese consumers, they have their own characteristics in terms of car use, entertainment, and social contact. On the other hand, as the high-precision map, interconnection communication, big data and other technologies of the intelligent connected vehicle industry are related to the national security field, which is highly valued and strictly monitored by the government, relevant enterprises engaged in the industry must be authorized by the state. As the ultimate form of the future vehicle, ICV has attracted many enterprises to flood in the industry with its great potential. The original traditional auto enterprises are undergoing rapidly transformation and new enterprises are constantly emerging. All parties are actively striving for high-quality resources and consumer groups, and the overall market is changing rapidly with fierce competition. The above particularity of the Chinese auto market will inevitably lead China to find an ICV road with Chinese characteristics that is different from other countries in the world.

In view of the development of ICV, scholars and relevant practitioners have conducted in-depth research in the fields of policies and regulations, strategic planning, industrial dilemmas, core technologies, and test sites in combination with the special circumstances of the Chinese auto market, and have proposed relevant development suggestions [2-6]. Based on the in-depth study on the current industry development status, this paper predicts the development trend of ICV from the perspective of intelligence and interconnection, analyzes the key issues arising from the different stages of intelligence and interconnection, and clarifies the development difficulties and priorities of each stage.

2. Overall Development Trend of ICV

ICV includes two aspects: intelligence and interconnection. The Society of Automotive Engineers (SAE) divides the intelligent process of ICV into five levels, Driver Assistance (DA), Partially

Automatic (PA), Conditionally Automatic (CA), Highly Automated (HA) and Fully Automatic (FA) [7]. In terms of interconnection, it is divided into three levels according to different functions realized: L1 is the connected auxiliary information interaction, L2 level is the connected collaborative perception, and L3 level is the connected collaborative decision-making and control. In term of technology, the development of intelligence and interconnection requires the penetration and integration of multiple fields, and the two cannot develop independently from the other side. In the future, ICV will show the development trend of integration alternatively led by intelligence and interconnection. In terms of market, due to the particularity of the Chinese auto market, the development of ICV shall be managed relying on the government's power of enforcement. Moreover, as the ICV industry is technically difficult and capital intensive, there are two development patterns within the industry. Technology-oriented and transformation-oriented service providers that occupy the technical commanding height by virtue of high-precision maps, computer vision and software algorithms actively lay out the eco-oriented industries with high value output. Combined with the demand for diversified travel modes in the Chinese market, the Chinese market will take the lead in realizing ecological leadership in the future. Therefore, under the dual-wheel drive mode of government and ecology, intelligence and interconnection will achieve overall improvement and coordinated development. Combined with the above analysis, the ICV development situation chart has been established, as shown in Figure 1.

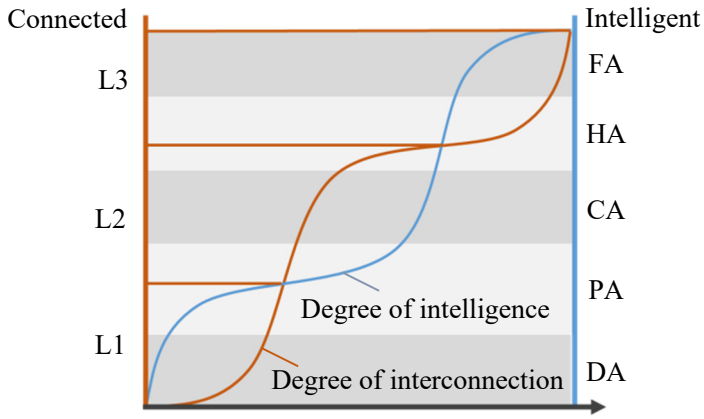

Fig.1 ICV development situation chart

The levels of intelligence and interconnection of ICV have fuzzy boundaries, among which the level of intelligence is the purpose and the level of interconnection is the means. In the early stage of development, automobile intelligence plays a leading role and leads the development of the whole industry. The demand for interconnection is not obvious, and the automobile reaches the DA level. At the PA level, with the intelligence reaching a certain level, the demand for more intelligent data increases, the requirements for information transmission efficiency and frequency of intelligent control of automobile gradually increase, and the demand for interconnection increases and exceeds that for intelligence. Interconnection is the basic technical means to realize automobile intelligence. At the CA level, more intelligent vehicle needs to integrate scenarios. There is an urgent need for breakthroughs in connected technologies such as 5G, high-precision maps and cloud platforms. Larger volume of data and higher efficiency are needed to realize V2X (vehicle to everything), so as to ensure the safety of intelligent driving. At the HA level, supported by connected technology, single vehicle gradually realizes a high degree of intelligence, and the system can complete all driving operations. At the FA level, vehicles are highly intelligent and connected. At this stage, the bottleneck of technology is no longer the most concerned issue in the industry. More demands of users need to be excavated, and the construction of ecological chain becomes the focus of the industry.

3. Key Issues at Various Levels of Intelligence Development

The intelligent technology of ICV enables the vehicle to independently identify, perceive, make decisions and control vehicle motion based on vehicle sensors and software algorithms [8]. Its development can be divided into three main stages, DA+PA level, CA level and HA+FA level.

3.1 Key Issues at DA+PA Levels

The DA and PA level are mainly based on autonomous environment perception and recognition, which can provide basic connected information guidance and realize intelligent driver assistance of single vehicle. External performance includes automatic emergency braking, adaptive cruise control, automatic driving in the lane, automatic parking, lane change assist, and car following.

The main generic technical issue at this stage is to achieve vehicle's high recognition of road, high reliability and real-time information exchange under simple condition. It includes two aspects, the accuracy of single sensor simple environment recognition technology and the reliability of vehicle bottom control modification. The current environmental recognition technology is mainly realized by utilizing hardware such as laser radar, millimeter wave radar and monocular/binocular vision, and by integrating customized algorithms related to auxiliary driving strategies. At the early stage of the development of automatic driving, it is mainly aimed at urban roads or expressways. The position and direction of vehicles relative to the lanes can be accurately obtained by detecting lane information. For the unstructured roads such as rural roads, however, more powerful recognition algorithms are needed. Therefore, in order to ensure the safety of drivers, simple environmental recognition rate should reach at least 95%. By processing and analyzing the data collected by the vehicle sensor, the autopilot system provides the vehicle with key environmental information, including the vehicle's position and speed, road shape, traffic signal, dynamic and static obstacles, and makes further control actions according to the surrounding environment. In the face of various emergencies, the vehicle's control action needs to ensure that the important parameters such as the position, attitude, speed and acceleration of the vehicle are in line with the latest decision. From the perspective of market, the volume and demand for non-autonomous vehicles at this stage is the main force. It is difficult for the structure of the driverless car to get rid of the mode of traditional car in a short time. The modification of control gear, throttle, brake, accelerator pedal, front suspension system, steering wheel, front wheel angle sensor, and assistant steering mechanism involved in it still must be paid attention to.

From the perspective of society, China's auto market has a large volume, and problems such as a large number of daily in-trip vehicles, traffic congestion, parking difficulties, and environmental pollution are becoming more and more serious. ICV can effectively improve traffic problems in large cities and meet the diversified travel modes of users. To solve the pain points of users is the basis of the development of ICV. It is necessary to plan and develop corresponding intelligent and connected technologies, lay out corresponding business models, and carry out the design of practicable automatic driving application scenarios centering on the scale of China's auto market and the particularity of consumer behavior. Based on the current vehicle volume and user demand, there must be the coexistence of multiple driving modes in the development process of ICV. As the most basic automatic driving mode, the assembly rate of new cars above DA level must be close to 100% in the future according to the demand of smart city traffic construction.

Standard specification is an important guarantee for promoting the sound development of ICV. Since the end of 2017, Beijing, Shanghai, Chongqing, Shenzhen, Changsha, Changchun and other places have issued relevant road-testing standards for ICV. The policy standards keep pace with the pace of technological development. The law, evaluation, insurance, information security, traffic enforcement and other related standards for ICV run throughout the whole development process of ICV. Therefore, at the DA and PA levels, domestic intelligent vehicles are still at the early application and testing stage. It is necessary to comprehensively consider the constitution and compatibility of standards, and comprehensively carry out the construction of standard policy specifications. In addition, it is necessary to formulate technology and application standards with an emphasis on the level of intelligence for China's unique road traffic and driving behavior characteristics, such as grading, terminology, automotive chips, general technical standards, etc.

3.2 Key Issues at CA Level

CA requires connected environment perception, which can adapt to the traffic environment with more complex conditions. Typical systems include expressway automatic driving, suburban highway automatic driving, coordinated queue driving, and intersection traffic assistance.

The main generic technical problems at the middle stage of ICV development include multi-source sensor perception information optimization combination, highly coupled vehicle autonomous decision control, and human-computer interaction common frame technology. ICV is originally designed to solve the problem of adapting vehicles to complex environment. Strengthening machine vision deep cognition and multi-source information optimization combination is an effective way to solve roads, rules and recognition in complex scenarios. On the one hand, deep learning technology is required to improve the detection accuracy and reliability of obstacles and high-speed targets. On the other hand, powerful network technology is required to meet the detection requirements under high-speed driving. Autonomous decision-making of highly coupled vehicles involves two aspects, hardware and algorithm. The best strategy for conditional autonomous control and trajectory planning of highly coupled vehicles is to independently develop and design chips and electronic circuits, develop and utilize connected perception information and automatic driving integrated decision controller, and integrate related algorithms such as ADAS image recognition, decision-making and control strategy integration and path planning. The above two technical breakthroughs in environmental recognition and decision control only solve the problem of insufficient human-computer collaborative driving ability in complex environments. In order to guarantee the reliability of intelligent vehicles on road, it is necessary to build the Chinese driver human-computer interaction behavior database for ICV as the underlying support layer.

From the perspective of industrial support, the CA-level products require a special systematic testing and certification method and corresponding testing environment. Therefore, it is necessary to study the testing method and technology of the intelligent & connected driving function, and formulate scientific and complete ICV testing and evaluation standard, ICV testing scenario database and data collection standard according to the particularity of the Chinese market. When it comes to stream data transmission, the problem of data standards and safety specifications must be solved, which is an important guarantee for multi-dimensional integration and real-time and efficient processing of vehicle data, traffic data and environmental data.

3.3 Key Issues at HA+FA Levels

The shift from HA level to FA level is a disruptive breakthrough. At this stage, the participation of traffic environment is improved, which requires the ability of connected and collaborative control between the vehicle and other traffic participants, the ability of fully autonomous perception, decision-making and control, and the realization of automatic driving under all road conditions such as expressways, suburban roads and urban roads.

The HA+FA levels aim to make the vehicle smarter, instead of more intelligent. The deep mining and application of data, as well as artificial intelligence technology, have become the main generic technical problems of the collaborative control between the vehicle and other traffic participants. Data is still the underlying support foundation. For scenario-like data, big data cloud computing technology is required to meet the requirements of different driving characteristics of vehicles in specific road environment. For industry-like data, it is necessary to build personalized market solutions and intelligent travel ecology through big data technology for the development of post-market business. Unlike the CA level, the HA+FA levels need to realize the autonomous judgment and decision of the vehicle and determine the travel path and driving path, rather than the “conditional highly coupled control decision”. The intervention of artificial intelligence technology will greatly enhance the efficiency of the vehicle to understand the external environment and make predictions and decisions through independent learning. This is of great positive significance to ensure the driving safety of intelligent vehicles.

At the level of industrial support, with the gradual transition of ICV to independent decision-making, the role of data teaching material, namely the role of scenario database, is gradually

highlighted. The construction of data teaching material should be considered from two aspects, the driver's driving behavior database for vehicle decision control and the all road condition scenario database. The establishment of the driver's driving behavior database for vehicle decision control can be carried out in four stages: extracting typical parameters describing driving behaviors, establishing behavior data structure and specifications, dividing typical groups and collecting driving behaviors of various groups, and storing data. The intelligent interconnection vehicle full-road scenario database can also be carried out from four stages: collection of various natural scenarios and typical scenarios, analysis and deconstruction of scenario elements, reconstruction of scenario feature models, and data storage scenario database generation. The database involves various aspects. In particular, it has to be coordinated developed and constructed with smart transportation. Therefore, it is urgent for the government to take a high degree of participation. Safety, management and other aspects should be considered to perfectly adapt the database construction to the new smart transportation system.

4. Key Issues at Various Levels of Connection Development

The interconnection of ICV is to solve the problem of information transmission in the process of driving and make assist the vehicle more intelligent. The L1 level is only information service and reminder of telematics (vehicle remote control and remote information reading), with low requirements for timeliness and reliability. The L2 level is V2X technology, which can accurately transmit information and assist vehicles in decision-making and control services. The L3 Level is used to support public cloud platform or LAN decisions.

4.1 Key Issues at the Level of Connected Auxiliary Information Interaction

Connected auxiliary information interaction mainly takes wireless voice, digital communication and satellite navigation and positioning system as the platform, and provides real-time traffic information, vehicle diagnosis, coping strategies, value-added services and other information services through positioning and wireless network [9].

With the development of information and communication technology, global communication can meet the basic requirements of V2X. The access network of ICV is inseparable from the common software and hardware platform of vehicle terminal, automotive chip, and the firmware upgrade scheme. Under the support of technology and policy, there are mainly two ways to realize connected auxiliary information interaction, T-BOX (remote information processor) and OBD (vehicle automatic diagnosis system), which are respectively oriented at Before Market and After Market. Communication interface, data resource, and protocol development degree are oriented at different applications. Although T-BOX and OBD play an important role in the popularization of V2X, they have made different distinctions on the market, population, age, function and so on. The objects and products they serve cannot be standardized, which affects the effective analysis of massive users and data. Therefore, how to obtain more effective data to enhance the experience of V2X is the main challenge at this stage.

4.2 Key Issues at the Level of Connected Collaborative Perception

Connected collaborative perception mainly refers to the accurate transmission of information with new wireless communication technologies such as DSRC, LTE-V or 5G as the carrier, and the collaboration with the information acquired by vehicle sensors to achieve V2X communication function and serve the decision-making and control of vehicles.

At the stage of connected collaborative perception, rapid interaction between the vehicle and the surrounding environment information needs to be guaranteed, and the requirements for timeliness and reliability are greatly improved. Therefore, the establishment of V2X communication standard at this stage is the most important task for the popularization of V2X. At present, there is no unified vehicle-to-vehicle communication standard in the world, and China has not yet launched a unified V2X communication standard. There are currently two major camps, DSRC and LTE-V. DSRC can realize the recognition and two-way communication of high-speed moving target in specific areas,

and transmit image, voice and data information in real time, such as vehicle-to-road and vehicle-to-vehicle two-way communication [10]. LTE-V technology solves the problem of "shared sensing" between traffic entities with LTE as the basis of communication. It can effectively extend the recognition range of vehicle sensors to more than hundreds of meters and multiply the efficiency of vehicle AI [11]. LTE-V technology does not require dedicated spectrum and can reuse existing infrastructure. Meanwhile, as a communication technology with proprietary intellectual property rights, it can help domestic enterprises avoid patent risks, and China will focus on the development of this V2X communication technology.

At the stage of connected collaborative perception, ICV starts to interact with external data in a large amount, and information security will become one of the urgent problems to be solved. In the aspect of ICV data security management, it is necessary to construct the automobile information security framework system with three dimensions of data storage, transmission and application. In the aspect of ICV data security technical standard, it is necessary to construct the "terminal-pipeline-cloud" data security system framework. It is also necessary to improve technologies such as data encryption, confusion, desensitization, audit, communication encryption, duplication, manipulation and counterfeit prevention, strengthen vehicle security gateway and safety monitoring system, formulate information security test specifications and standards, classify and summarize the application of data security technology of ICV, and ensure that data technology can be implemented and supervised.

4.3 Key Issues at the Level of Connected Collaborative Decision-Making and Control

The stage of connected collaborative decision-making and control refers to the interconnection of network system decision-making and control in the future, which needs to be carried out with the assistance of high-precision map and positioning technology through the intelligent cloud control basic platform. At the same time, it is necessary to realize the decision-making and control based on interconnection, and even control the vehicle in real time through interconnection. The technology at this stage is the connected technology in a complete sense.

The construction of high-precision map and the realization of high-precision positioning are important sources of environmental information for vehicles. It can help the vehicle driving system perceive a wider range of traffic situation and ensure the safety of automatic driving. Meanwhile, it can also help the vehicle make independent path planning and decision support, with the advantages of multiple dimension, timely update, and result of centimeter-level accuracy. Therefore, the construction of high-precision map has become the key driving force for the implementation of autonomous driving technology. There are two kinds of high-precision map modeling technologies. One is the heavy map mode in which a high-precision map is drawn through GPS positioning after background processing with data acquisition vehicle as the collector of source information of high-precision map. The other is the light map mode that uses vehicle cameras to collect the characteristics of specific roads to help the vehicle navigate.

Based on high-precision map, from the perspective of technology, basic data of safe operation of vehicles such as vehicle operation data, traffic and highway administration data and environmental public service data can only be used by developers of technologies such as automatic driving, intelligent travel and intelligent transportation by virtue of the intelligent cloud control basic platform. Therefore, to realize the practicability of interconnection, it is essential to build a big data cloud control basic platform.

5. Critical Path for Integrated Development

The essence of ICV is the combination of autonomous intelligent vehicle and connected intelligent vehicle. The autonomous intelligent vehicle is dominated by intelligence, which actively detects the surrounding environment through sensors, and makes intelligent driving behavior through the understanding of the environment within the scope of vision. The connected intelligent vehicle is dominated by interconnection, which passively receives adaptive responses made by other vehicles,

facilities and cloud information (high-precision electronic map, etc.) to solve the obstacle avoidance outside the scope of vision and improve driving safety and efficiency. In the development process of ICV, the two must be mutually integrated and promoted.

5.1 Key Issues of the Integration of Intelligence and Interconnection

In the development process of ICV, the key technical problem that is the most difficult to be broken through is integration. ICV is equipped with a variety of sensors and communication devices that are used to acquire information of different categories and ranges, such as vehicle radar for recognition within 200 meters, visual sensor for recognition within 80 meters, and dedicated short-range communication for information transmission within one kilometer. The information complements each other, but at the same time there are contradictions between the information, and the safe driving of intelligent vehicle must ensure the only and correct instruction. In order to ensure the real-time, reliability and redundancy of information acquired by ICV, the integration of intelligent information and connected information is an inevitable trend. The combination of sensor and network enables the integration of far, medium and near spatial dimensions. In terms of time dimension, the range of 5 seconds to 20 seconds is solved by short-range communication, and more than 20 seconds is solved by mobile communication. In the same period of development, in order to ensure the unity of the two kinds of information in space and time dimensions, it is necessary to further determine the specific integration issue, such as decision-level integration, feature-level integration, and data-level integration. On the other hand, the algorithm is the core of information fusion processing. Ensuring that the algorithm is sufficiently optimized, fast and fault-tolerant will also become a key issue in driving decision-making.

5.2 Industrial Service Issues of the Integration of Intelligence and Interconnection

In the future, the development trend of automobile will be interconnection, intelligence and electrification. The automobile industry will undergo revolutionary changes: the emergence of new auto products, parallel new industrial chains, reconstruction of the automobile industry, and fuzzy industrial boundaries. Intelligent vehicles, intelligent transportation, smart energy, and smart cities are intertwined and inseparable. As a major auto sales country, the Chinese auto market will maintain a steady growth for 10 to 15 years, and the sales volume is expected to reach 40 million in 2030. Therefore, based on the demand of the Chinese market, ICV will be landed in China first, presenting take the lead in China, presenting people-oriented diversified and innovative services, and finally realizing the intelligent travel ecosystem with multiple industrial chains. In terms of industrial value, the value volume of automobile design, research and development, post-market service, and operating mode increases dramatically, and mobile travel brings about infinite possibilities. Therefore, enterprises need to pay more attention to the marketing mode, maintenance mode and operating mode under the ICV industry. The deep integration of information technology, mobile Internet technology and traditional transportation will bring about more changes in business models. The future urban transportation mode will be a structure in which multiple means of transportation coexist and multiple modes of transportation are combined. Product form and response speed will become the key factors of ecological construction of travel.

6. Summary

According to the research on the key issues in the development process of intelligence and interconnection of ICV, limited by industry standards and national policies and regulations, the research still focuses on the core technologies of intelligence and the communication facilities of interconnection, and the research on the integration of intelligence and interconnection has not yet been fully carried out. In the future, ICV will not rely solely on intelligent technology or connected communication to achieve safe travel, so the integration of related technologies and industries needs to be further studied.

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