The Digital Transformation of Cars

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ABSTRACT

With the development of science and technology, digital technology is gradually applied in all walks of life to improve efficiency and function. The automobile industry is also involved in this digital transformation, and the networked automobile is the product of automobile digitalization. Vehicle to Cloud (V2C), Vehicle to Infrastructure (V2I), and Vehicle to Vehicle (V2V) technologies emerging in digitalization constantly improve people's daily travel, but there is also a problem of low popularity. In order to deal with this problem, this paper reasonably assumes that the existing methods and technologies will be integrated into a system. Since the number of road accidents is still numerous, the V2V communication technique needs to be adopted in a brand-new driving system that is compulsory to be installed into every car. The driving system is supported by three methods: sensors, cloud computing, and 5G. Those methods can provide functionalities like information transmissions or data collection. Market situations of these three main techniques are analyzed in this article, and data shows substantial and increasing demands in those markets by estimated Compound Annual Growth Rate (CAGR) and market sizes. In addition, issues of private security and the future of intelligent car technology will also be discussed in this paper.

Keywords: *Digital transformation, Automobile, Sensor, Cloud computing, 5G*

1. INTRODUCTION

In today's world, digital transformation has penetrated all walks of life. Digital transformation has fundamentally changed the behavior of enterprises and consumers and brought tremendous pressure to traditional industries [1]. For example, online retailers like Alibaba and Amazon almost destroyed offline retailers, Spotify changed the music industry [2], Netflix changed the TV broadcasting and movie industry [3]. Therefore, digital transformation has almost become the most important means for all walks of life to enhance their competitiveness, and so are the car industry.

The product of the digital transformation of the car is the connected car. The significance of the emergence of connected vehicles mainly has the following two points: First, with the support of explosive growth of available data, digitalization can improve efficiency, save costs, break the original value chain model and create new value for the car industry; The second is to bring comprehensive benefits to society. Connected cars can digitize transportation and reduce road accidents and air pollution [4].

At present, the research on connected cars mainly classifies the forms of connection technologies, which are primarily divided into several types [5] such as Vehicle to Cloud (V2C), Vehicle to Infrastructure (V2I), and Vehicle to Vehicle (V2V). Among them, V2C consists of data exchange between vehicles and clouds. V2I consists of two-way information exchange between vehicles and road infrastructure [6]. Vehicles can obtain road information from road infrastructures such as cameras and traffic lights, thus significantly increasing the safety of vehicles [6]. V2V consists of information exchange between vehicles, and vehicles share information such as speed, position, and heading [6]. Because V2V mesh design can grasp all the world information within 300 meters in real-time, NHTSA said this technology could avoid 615,000 traffic accidents [6].

Despite the rapid development of connected vehicles in recent years, the penetration rate of V2C, V2I, and V2V technologies is still not high, and road safety is still

a big problem. According to Road accidents in the United States - Statistics & Fact [7], about 12.15 million vehicles were relative to crashes in the United States in 2019. This hurts personal safety and brings a lot of economic losses.

In order to solve this problem, this paper assumes to make rational use of the existing technologies and integrate them into a critical unified system suitable for all kinds of vehicles. The procedure involves three main methods and techniques. The first is sensor technology, which is an essential guarantee for the system to obtain data for analysis. Second, cloud computing technology, according to the characteristics of cloud computing distributed computing, can have categories high-speed analysis of the data obtained from the sensor while realizing different functions simultaneously to ensure fast. The third is 5G technology and 5G MEC, which are critical for learning the above processes. With the guarantee of the two technologies, no information delay can be realized, the danger caused by information lag can be avoided, and higher security deployment can be established.

The remainder of the paper is organized as follows. Section 2 gives background information and previous research results of sensors, cloud computing, and 5G. Section 3 provides details about the system, including the realization of the V2V and V2I communication and the integration of related technologies. The section also introduced how to apply these technologies to the system mentioned in section 2. Finally, section 4 gives some concluding remarks.

2. RELATED WORK

The use of sensor technology in a conventional car can help the driver see what is going on around the vehicle and adjust the temperature inside the car and seat functions according to the driver's physical condition. Through more advanced sensors, the driver can even communicate with the intelligent system built in the car, realizing artificial intelligence in the automotive industry. Sensors are tools used to detect the self and environmental conditions of subjects such as vehicles and roads and are also the hardware foundation of the Internet of Vehicles. The sensors currently used on the Internet of Vehicles industry are mainly divided into image sensors, lidars, ultrasonic radars, and biosensors [8].

At present, there are many research achievements in the academic circle on the sensor in the car. For example, Alessio Carullo and Marco Parvis work on a sensor that measures the distance from the vehicle's location to the ground. Such sensors greatly help people as a parking aid [9]. In addition, the technology using image sensors has also made significant progress. The unlimited operational data exchange enables the system to monitor and identify moving vehicles using image or video processing [10]. This technology has entered the experimental stage. Sensors designed for cars also include spectral carbon dioxide sensors. This sensor utilizes the infrared measurement principle and is suitable for automatic ventilation systems in vehicles [11].

The digital transformation of enterprises needs to establish a digital platform that can support the real-time perception of changes, real-time analysis of changes, real-time making of optimal decisions, and automatic implementation of decisions. Cloud computing is a type of distributed computing in which an extensive data processing program is decomposed into countless small programs over a network called the "cloud." Then these tiny programs are processed and analyzed by a system made up of multiple servers to obtain the results and return them to users [12]. Cloud computing can analyze massive data collected by sensors and provide a basis for making correct strategies. It is an indispensable technology in digital transformation. The foundation of the success of digitalization is to regard "data" as an "asset." Cloud computing can help enterprises conduct digitalization through the whole business process, connect the data of various departments, realize system intercommunication and data interconnection among different departments, and integrate data across the entire line, enabling the business and providing accurate insight for decision-making.

Currently, cloud computing has achieved a lot on the Internet of Vehicles, including making significant contributions to building smart cities. Cao Bin and Sun ZH's experiment guarantees the low latency requirements of the current intelligent transportation system [13]. In the complex and dynamic IoV environment, efficient architecture and resource allocation algorithms are designed to effectively manage the computing resources with different attributes and provide high-quality services. In addition, there are new algorithms based on IoV architecture that can be used to assist intelligent vehicles in solving traffic monitoring, road safety, and management problems in collaboration to help deal with a large amount of data in cloud computing, which will also be applied to ordinary cars, thus accelerating the construction of intelligent transportation [14].

High speed and low time delay are essential indicators of successful transformation in the digital transformation of automobiles, so 5G is a necessary technology in the digital transformation of automobiles.5G Network refers to the fifth-generation network in the development of mobile communication networks. 5G networks show more enhanced functions in practical applications compared with the previous four-generation mobile networks. Theoretically, its transmission speed can reach tens of GB per second, which is hundreds of times that of 4G mobile networks. The 5G network shows more apparent advantages and more powerful functions in practical application [15].

5G technology has helped solve many problems on the Internet of Vehicles and laid the foundation for future development. Arooj and Farooq are gaining an in-depth understanding of the road topology, connected vehicles, and traffic trends and proposing an efficient route planning framework for social media flows with users. Simulation results show that the framework can realize the human-computer intelligent association of intelligent environment management [16]. Besides, With the intellectualization and interconnection of IoV technology, V2X communication technology has become the core technology of information interaction between intelligent, interconnected vehicles. It is also an important technology to realize the perception of the future automatic driving environments. In order to provide wireless communication services with ultra-low delay, ultra-high reliability, and ultra-large bandwidth, research has now been conducted to propose the architecture of a 5G-V2X communication network by utilizing 5G New Radio (NR), network slice, and device-to-device communication technology [17].

3. METHODS

3.1. Overview

The driving system is an integrated system that connects all kinds of sensors installed in connected cars and digital process information by cloud computing techniques. There are three types of sensors: image sensors, temperature sensors, and heart rate and respiration sensors. The data those sensors capture can be processed by the driving system. The system can send instructions to machines like air conditioning or audio systems to give a better driving experience to the drivers. Moreover, this system can also achieve V2V and V2I communication. The wireless digital transmission modules can be installed in the driving system within the connected cars and traffic signal system, and the digital signal can be transmitted, disassembled, and processed between those modules by using cloud computing techniques, and that digital information also can adjust the reaction of machines in connected cars. In addition, cloud computing also deals with the data transmitted from sensors. It decomposes and processes the information quickly and helps the driving system to make a decision as soon as possible. The 5G network is the basis to support the above functionalities of the driving system, and MEC (Multi-access edge computing) is a powerful technology to accomplish information transmissions without lag. To be more specific, MEC is a technique used in communications to improve efficiency; it is based on short proximity of data transmission to reduce the time of signal transmissions. In addition, third-party digital platforms also can be introduced with robust connections and powerful signal transmissions. The diagram below gives an overview of the system.

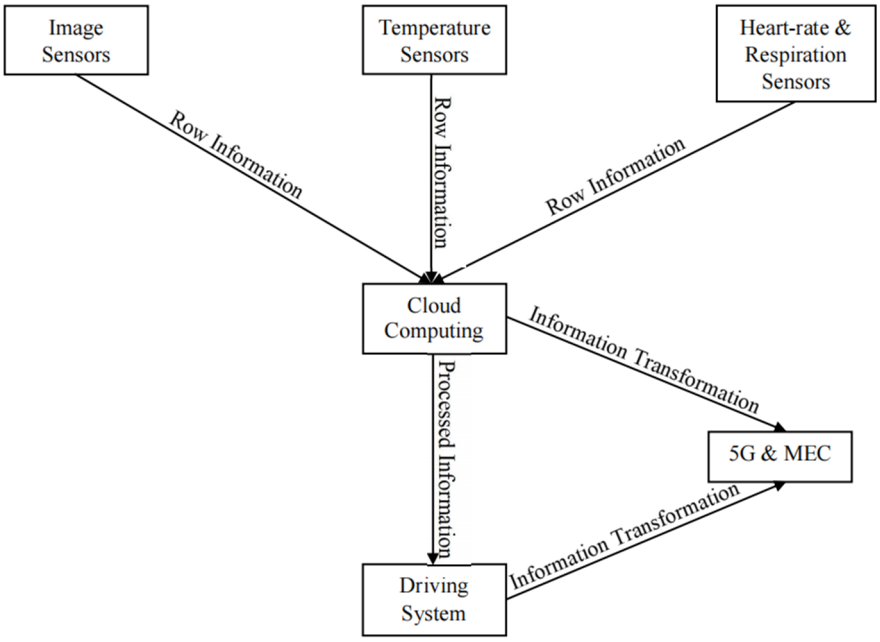

Figure 1. Overview of the system

3.2. Sensors

Automotive electronic control systems generally follow a workflow where perception controls actions. As a sensing unit, the sensor obtains the working state of the vehicle so that the control unit can process the sensor signal and calculate and output the control command. Finally, the execution unit completes the corresponding action. Due to the critical role of automotive sensors in automotive electronic control systems and the rapidly growing market demand, countries worldwide attach great importance to their theoretical research, new

material applications, and new product development. The general development trend of future automotive sensor technology is miniaturization, multi-function, integration, and intelligence. The functions that the sensor will implement in this system are:

3.2.1. Detection of objects

Image sensors can identify, detect and track objects on the road. We think that designers can communicate with manufacturers to install cameras that can monitor the environment as image sensors around the outer frame of the original vehicle. After the image sensor receives the visual signal, it transmits the code to the control system. After collecting various environmental information, the system can classify the driving environment of the car into congested road conditions, normal road conditions, or emergency road conditions. In emergency road conditions, the voice system of the car will remind the driver to pay attention to the road conditions, be careful of the fronting car which takes an emergency stop, and estimate the duration of the traffic jam. The voice system will inform the driver of regular traffic ahead in normal road conditions. In cases of emergency road conditions, the voice system will notify the driver of the emergency braking and the location of the emergency road condition. This road condition analysis technology compensates for the delay of human vision and senses, allows drivers to detect possible dangers in the shortest time, and improves driving safety. This Application can also be applied to autonomous driving technology to monitor road condition information in real-time, replacing the original human visual monitoring.

3.2.2. Adjust the cabin temperature

Special in-vehicle sensors sense the real-time temperature in the car through the contact terminal and determine the driver's mental state by analyzing the driver's heart rate and breathing rate. The temperature sensor part can sense the air temperature in the car, and the existing temperature sensor brand can be chosen - such as Siemens's temperature sensor - for implantation. The system can adjust the temperature in the car according to the current weather conditions and the driver's preferred temperature when the system receives temperature data. The car's heart rate and respiration sensors can evaluate the driver's mental state through the data collected by the sensor. If the driver's heart rate and breathing rate are too slow, the intelligent voice system will remind the driver not to drive tired by playing music and voice prompts. If the heart rate is too fast, the system can calm the driver's emotions by appropriately reducing the temperature in the cabin. This function can provide drivers with comfortable and customized driving services, allow drivers to travel with confidence.

For the categories of image sensors, there could be two kinds of sensors, which either are CMOS (Complementary metal-oxide-semiconductor) sensors or CCD (Charge-coupled Device) sensors. In traditional machine vision, CMOS or CCD image sensor, which samples the visual area tens to thousands of times per second, detects the motion [18]. From the CMOS image sensors aspect, the market size is growing steadily in the forecast. From 2021 to 2025, the CMOS image sensor market will increase by $ 10.80 bn at a 10% Compound Annual Growth Rate (CAGR) [19]. This market trend indicates that the need for image sensors is rising, which means the image sensor is valuable to be a part of the driving system to make its functionalities more worthy.

The need for temperature sensors in the automobile market is also climbing, which leads to increasing demands for more advanced technology in the temperature sensor area. The automotive temperature sensor market and healthcare use technological advancements [20]. From the market size perspective, it shows the developmental tendency. From 2021 to 2022, the expected growth of the global temperature sensor market is from $7.50 billion to $8.05 billion at a 7.3% CAGR [20]. The estimated growth analysis of TBRC's temperature sensor market shows that the market will increase to $10.49 billion at a 6.9% CAGR in 2026 [20].

To sum up, the demand for temperature sensors is continuously increasing in five years. The heart rate sensor market also demonstrates a relatively high CAGR, which means the space of development and demand level of this sensor are significant. From 2017 to 2023, the heart rate monitor market's estimated growth is at a CAGR of 13.50% [21].

3.3. Cloud Computing

The Internet of Vehicles service platform's vast data collecting, storage, and computation speeds up data operations and processing. The networked Application of multi-functional subsystems may be optimized. A relatively high-security deployment can be set up by immediately bringing cloud computing into the Internet of Vehicles operation service management platform. The integration of cloud computing 4G/5G, RFID, EDI, and other communication technologies can enable the storage of large amounts of data, the integration of virtual network and information services, and the interaction and data exchange of systems in other domains [22]. The functions that cloud computing will implement in this system are:

3.3.1. Road facilities interaction

The basis and guarantee for the compatibility of traffic systems is the compatibility of traditional vehicles with traffic signals (signs, lanes, speed limits, traffic lights, and so on). After that, the wireless digital

transmission module is transplanted into the road traffic signal system to be changed. The required information is returned to the related networked vehicles by obtaining the inquiry information and the navigation request of those networked vehicles. Connected vehicles gain the digital information of the traffic signal system by transplanting it to the wireless digital transmission module of those connected vehicles, then display the information in the vehicles, and connect the information with the driving system in the vehicles as the control signals for automatically driving the vehicles.

3.3.2. Vehicle Interaction

The wireless digital transmission module is transplanted into the connected vehicles, providing digital status information for those vehicles and sending traditional signal information and digital information together. The wireless digital transmission module of the related vehicles can synchronously obtain the digital information of different interconnected vehicles, display the digital information in the vehicles simultaneously, and connect and interact the information with the in-vehicle driving system as the basis for the safe driving of the connected vehicles.

To sum up, cloud computing will ensure flexibility and high speed of V2V communication in the future intelligent transportation environment, realizing driving safety, entertainment and reliability.

Cloud computing can be used for faster and more convenient data processes and storage through the internet. For the connected car, a considerable amount of data needs to be processed in a minimal time to guarantee driving security; therefore, cloud computing is a vital technology to use. The worldwide estimated cloud computing market size will grow from $445.3 bn in 2021 to $ 947.3 bn in 2026, and the CAGR will reach 16.32% [23]. The significant growth of demand scale in cloud computing implies a strong development trend.

3.4. 5G Network

The characteristics of 5G improve the vehicle's perception, decision-making, and execution ability to the environment and bring good primary conditions to the Application of vehicle networking and automatic driving, especially those involving vehicle safety control. It can be seen that 5G plays a significant role on the Internet of Vehicles and is an indispensable part. The 5G+ Internet of Vehicles connects critical elements such as "people-cars-roads-clouds", builds the interconnection of data in the transportation field, forms intelligent decisions based on data, and promotes the landing of related applications. The functions that the 5G network will implement in this system are:

3.4.1. Combine with cloud computing

The 5G network is based on central, regional, and edge data centres to build a distributed cloud. It will enable the integration of MEC (Multi-access Edge Computing) and C-V2X. The cooperative perception, decision-making, and control of the vehicle cloud will be realized by integrating network communication, calculation, and storage in the vehicle network. MEC provides wireless network capability, IT business environment, and cloud computing capability near the network edge of users and has the characteristics of available network capability, low latency, high performance, local services, and so on. The MEC's local shunting capability can significantly reduce the transmission delay of car networking applications and is suitable for deploying safe driving businesses. The MEC provides a network information opening function to open the edge network through standardized interfaces, including wireless network information (RNIS), location information, user information, and so on. [24].

3.4.2. Enrich vehicle-mounted equipment

5G enables the communication range to be extended and expanded, realizes the accurate positioning of information data simultaneously, avoids the spatial dispersion of adequate data, ensures the synchronization of data transmission, and effectively reduces the interference of urban buildings to a certain extent. This also provides a premise for developing transportation in smart cities, realizes the diversity of people's activities in cars, and introduces more third-party platforms.

5G is a vital technique to support the information transmission of connected cars. To understand the 5G market, MEC (Multi-access Edge Computing) as an important technology to assist 5G can be analyzed at first. From 2017 to 2025, the MEC market is expected to grow at a CAGR of 51%; The estimated revenue will increase from US$73.8 Mn in 2016 to US$ 4228.3 Mn by 2025 [25]. To be more macro, the overview of the 5G market also shows the rising needs of 5G technology. Till the end of 2026, global 5G mobile subscriptions will reach 4.1 billion, which obtains 37.1% of total worldwide mobile subscriptions [26].

4. CONCLUSION AND FUTURE WORK

This paper first introduces the broad Application of digital transformation then shows that the Application of digital in the automotive industry can improve road safety. A detailed analysis of the three technologies necessary for digital transformation shows the possibility of digital realization in the automotive field. At present, the digital transformation trend of the automobile industry is to collect comprehensive data through the use of various sensors, analyze and calculate massive data,

formulate the optimal road planning scheme, and realize the construction of intelligent urban transportation.

Attention should be paid to privacy issues in future research. For example, when the sensor scans the road conditions, it will scan pedestrians' facial features, and the car's voice function will capture the details of the user's conversation. Privacy issues include addressing security and privacy attacks such as authentication and identification attacks, availability attacks, confidentiality attacks, routing attacks, and data authenticity attacks. Another potential danger is the infringement of intellectual property rights. With the rapid development of Internet technology, the channels and ways of obtaining electronic data resources at low cost are more diversified and convenient, and the new electronic map version is more vulnerable to infringement, thus affecting the business of a four-dimensional new electronic map and the operating income of software products. NavInfo is constantly strengthening the research and development of new technologies and products in autonomous driving, intelligent networking, and new energy vehicles. In the process of collecting and using research and development tools and basic agreements, protecting research and development results, and secondary development and utilization, NavInfo's software copyright, patent rights, and trademark rights will also face the risk of infringement.

Questions about intelligent cars that require further research include:

(1) The future of intelligent cars is likely to include a variety of technologies that are not currently in place. The ability to use insights from data to diagnose and fix problems proactively is precious as cognitive cars need to handle more maintenance situations on their own. Its future cars can use AI technology to organize and enrich "thinking" and "actionable" data to meet business needs for automatic diagnosis and maintenance.

(2) Purpose-built vehicles are also what consumers expect. Parents with two children want the car to be equipped with a child safety seat. Seniors with medical needs want cars equipped with the medical equipment they need. People with disabilities need easy access and store equipment such as wheelchairs. Finally, the automotive industry can inspire various industries (such as tourism) and then introduce custom-made automotive systems.

(3) Consumers expect their data to be very safe and their privacy protected. The problem is compounded by e-hailing or car-sharing services, both of which have to access personal data during the actual use of the car. However, that data cannot be shared with rival brands of cars. Therefore, regardless of the mobility platform used, the ability to transmit personalized digital information between different vehicles of the same brand and enhance the security level of personal information can create innovative car loyalty.

AUTHORS' CONTRIBUTIONS

The contributions of all authors are equal.

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