OPERATING SYSTEM TECHNOLOGY TRENDS FOR AUTONOMOUS VEHICLES

Seung Ju Jang
College of ICT Engineering, Dong-Eui University
Korea
sjjang@deu.ac.kr

ABSTRACT

Autonomous vehicle technology is improving rapidly. Currently, autonomous vehicle technology is starting to be commercialized. Until now, many companies have put a lot of effort into developing technologies related to autonomous vehicles. The commercialization of self-driving cars is accelerating. This paper look into the technological trends of autonomous vehicle operating systems. We look at the development trend of operating system technology, which is a core technology in autonomous vehicles at the time of entering the commercialization stage. Global automakers and IT companies are competing in the development of autonomous vehicle operating system technology. We study the operating system technology for autonomous vehicles being developed by global companies.

Keywords: Operating System, Autonomous Vehicles, OS Technology.

INTRODUCTION

Currently, autonomous vehicles technology is entering the commercialization stage. Until now, many companies have put a lot of effort into developing technologies related to autonomous vehicles. The commercialization of self-driving cars is accelerating. <Table 1> shows the recent autonomous vehicle sales scale and expected sales scale.

Table 1. Global Market Size and Prospect by Level of Self-Driving Vehicles (Unit: billions of dollars, %)

		2020	2025	2030	2035	CAGR
World market	Limited autonomous driving(Lx3)	63.9	1,234.80	3,456	4,905	33.6
	fully autonomous driving(Lx4)	6.6	314.1	3,109.20	6,299	84.2
	total	64.5	1,548.90	6,565.20	11,204	41

<Source : Autonomous Vehicles, Navigant Research/ Strategic Analysis of the European and North American Market for Automated Driving, Frost&Sullivan, https://www.irsglobal.com/bbs/rwdboard/15302>

Automobiles are evolving from simple mechanical devices to self-driving car technologies that make decisions on their own. The computer system function is very important for autonomous vehicles to make their own decisions and operate in this way. The car is equipped with a computer and the computer decides to drive the car. In this way, the automobile is being transformed into a mechanical device in which the function of a computer system is the core.

S/W(Software) installed in the computer required for autonomous driving will play a very important role. Automobile manufacturers around the world are leading the technology by developing their own operating system.

As of 2017, the cost share of software in automobiles was 52.4%, higher than that of medical devices (40.9%) and slightly lower than that of mobile phones (54.3%). More than half of the cost of creating autonomous vehicles is related to software [1, 2, 3]. The reason why the cost of autonomous vehicles is high is that many functions are implemented and various sensors must be installed to implement these functions. In particular, the number of ECUs (Electronic Control Units) is continuously increasing.

AUTONOMOUS VEHICLE TECHNOLOGY

Autonomous vehicle technology refers to a system that the vehicle drives itself and drives it to its destination without human assistance. In relation to the function of the autonomous vehicle system, the Society of Automotive Engineers (SAE) has defined six levels from Level 0 to Level 5 [1, 4, 5].

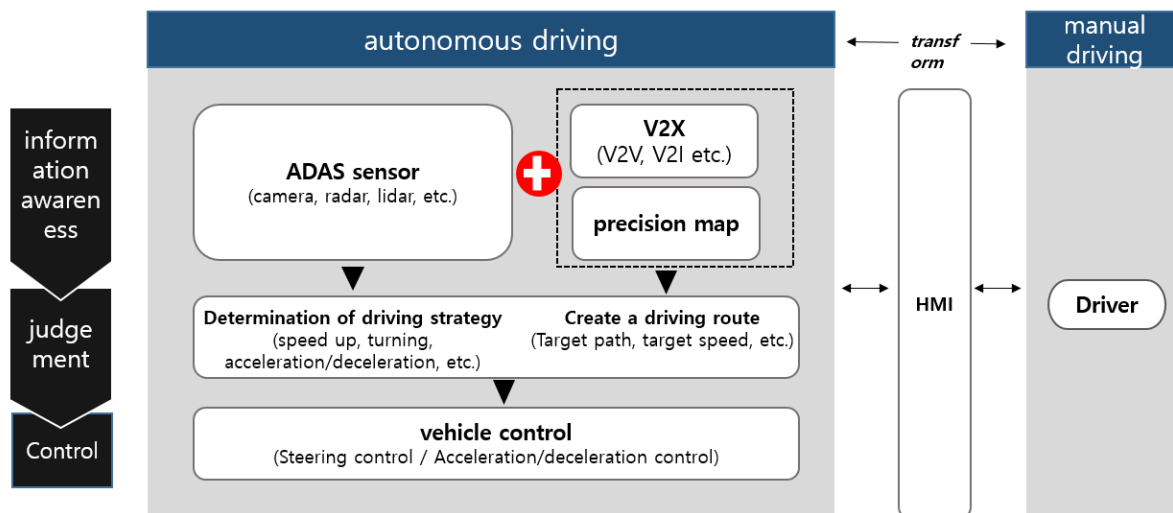**Table 2. Stages of autonomous vehicle function <Source: SAE>**

Level classification	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
designation	No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
automation items	None	steering or speed	steering or speed	steering or speed	steering or speed	steering or speed
watch driving	always required	always required	always required	system request	Not required within the operating range	No need for all operations
automation range	.	specific range	specific range	specific range	specific range	Full range

Level 0 refers to the stage in which the driver of the vehicle controls and operates all the device operations of the vehicle. All operations of automobile devices are performed by a human, which corresponds to conventional automobile driving. Level 1 is a stage in which the vehicle receives support for steering assistance or acceleration/deceleration system functions, but still a person has the authority to drive the vehicle.

Level 2 is the stage in which autonomous vehicles support steering and acceleration/deceleration functions, but human takes a role in judgement and driving in relation to driving. In Level 3, autonomous vehicle systems are responsible for driving, but when a driver's intervention is requested, the driver must take appropriate control of the vehicle.

In Level 4, the autonomous driving system operates with the control right in all situations such as core control for driving, monitoring of driving environment, and response in case of emergency. There is driver intervention when necessary. Level 5 is a fully autonomous driving mode, in which the autonomous vehicle system operates the vehicle through all judgement and control under all road conditions and all environments.

The system structure for fully autonomous driving according to the autonomous vehicle system level is shown in <Figure 1>.

<source : suresofttech, "The technology and future of fully autonomous vehicles", 2017.6. [4]>
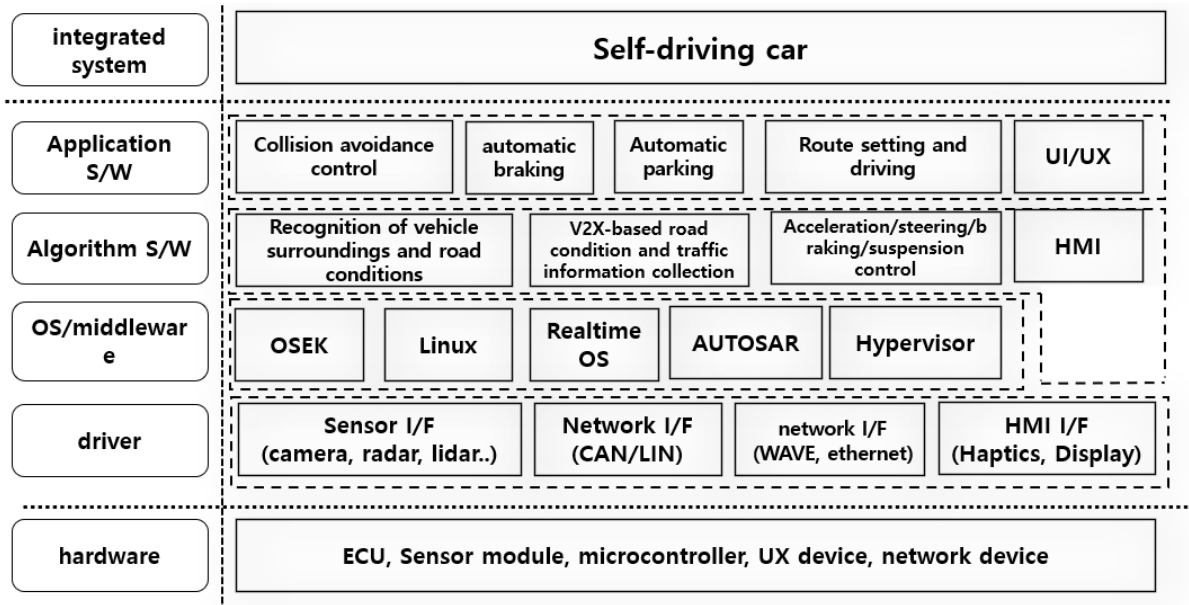
Figure 1. Autonomous vehicle system structure

The functions of autonomous vehicles largely consist of perception, judgement and control. The minimum basic functions required for autonomous driving are various sensors that recognize the driving environment. And, for a highly autonomous driving function, it must have precision map and communication function.

ADAS (Advanced Driver Assistance Systems) is an intelligent driving assistance system, and sensors, Geographical Positioning System (GPS), communication and image processing related equipment support such intelligent driving assistance systems. Through such a driving assistance system, it is possible to control the vehicle by judging the situation while the vehicle is driving.

V2V (Vehicle to Vehicle) communication is an important technology for autonomous vehicles. V2V communication must ensure that it operates with a high data transmission rate and low latency to increase safety.

AUTONOMOUS CAR OPERATING SYSTEM TECHNOLOGY
We will examine the operating system dedicated to autonomous vehicles as a core technology for accurately controlling the vehicle as autonomous vehicle technology develops. The autonomous vehicle S/W system structure is shown in <Figure 2>.

<source : KESSIA Issue Report >

Figure 2. Autonomous Driving Vehicle Software System Structure

As shown in <Figure 2>, an autonomous vehicle consists of SW that can determine driving conditions, SW that establishes driving strategies, and SW that controls parts such as sensors. The technology related to the function of receiving and controlling information through various parts such as sensors in autonomous vehicles is also developing in various ways. Even before autonomous vehicles, ECU modules for electric and electronic functions in automobiles have been continuously increasing. Recently, technology development of a centralized method that integrates and manages these ECUs is in progress [6, 7, 8, 9].

In relation to the control of automotive electronic components, technology has recently developed into an integrated platform operating system environment. The development of an operating system for an autonomous vehicle SW platform is a core technology required for a vehicle to drive itself. This paper explains the development trend of operating system technology in SW platform related to autonomous vehicle operation. Currently, autonomous vehicle developers are focusing on developing their own operating systems. Therefore, autonomous vehicle development companies are putting a lot of effort into developing such an operating system [10, 11, 12].

The research on the core operating system that judges and controls autonomous driving in autonomous vehicles can be summarized as follows <Table 2>.
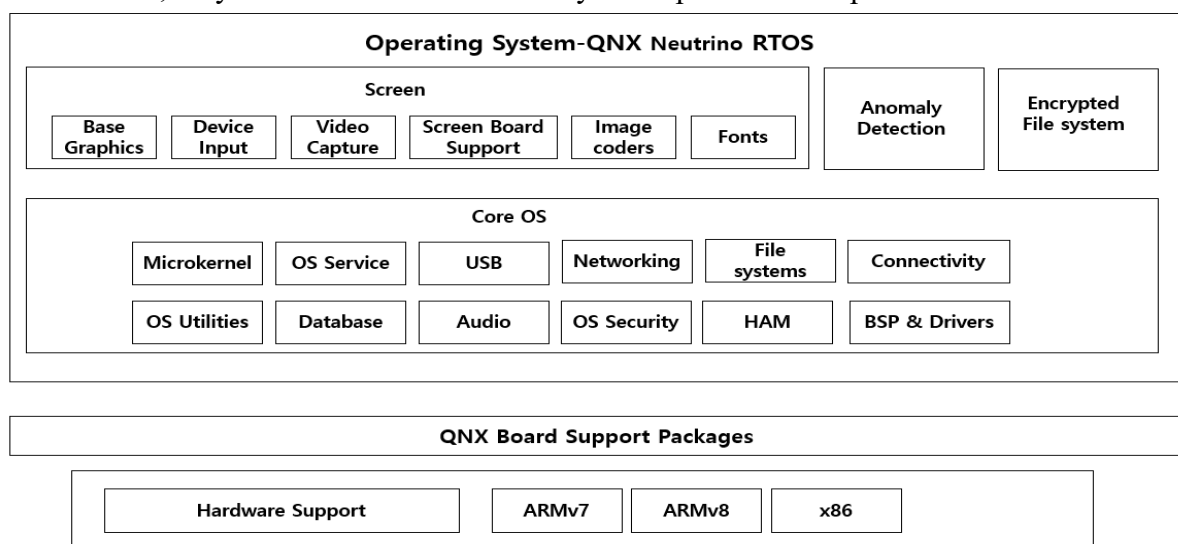
QNX is an operating system related to autonomous vehicle driving. The QNX operating system is an operating system developed by Blackberry. Blackberry is a company that makes smartphones and is developing autonomous driving technology.

Table 3. Autonomous vehicle operating system

Company	Operating System Name	Function
Blackberry	QNX	Satisfaction with RTOS function Ensure real-time job processing Slimming of kernel functions
Tesla		Make software upgrade easy (provided OTA function) Centralized control to reduce the number of ECUs
Hyundai Motor	ccOS	Provides functions related to driving as well as infotainment based on Linux kernel
Volkswagen	VWOS	Flexible platform design to be applicable to all vehicle types
Apple		Centralized system management Commercialized by loading software on Apple Car
Toyota	Aran	Developing its own software 'Aran' Participated in the Linux-based AGL consortium
Google	Android Auto	Provides interworking function with Android environment Expansion of technology application in the automotive field by utilizing smart phone SW technology

The BlackBerry QNX operating system has been applied and used in fields that are not very closely related to automobile driving, but is now being applied and used in parts related to automobile driving. The QNX operating system satisfies the RTOS (Real Time Operating System) function. It is mainly used where real-time job processing guarantee is required. For autonomous vehicles, real-time satisfaction is very important. Recently, the scope of use of the QNX operating system is expanding to the area of autonomous vehicles.

The QNX operating system has a microkernel structure. Since the function of the kernel is slimmed down, only the basic functions of the system operation are operated within the kernel.
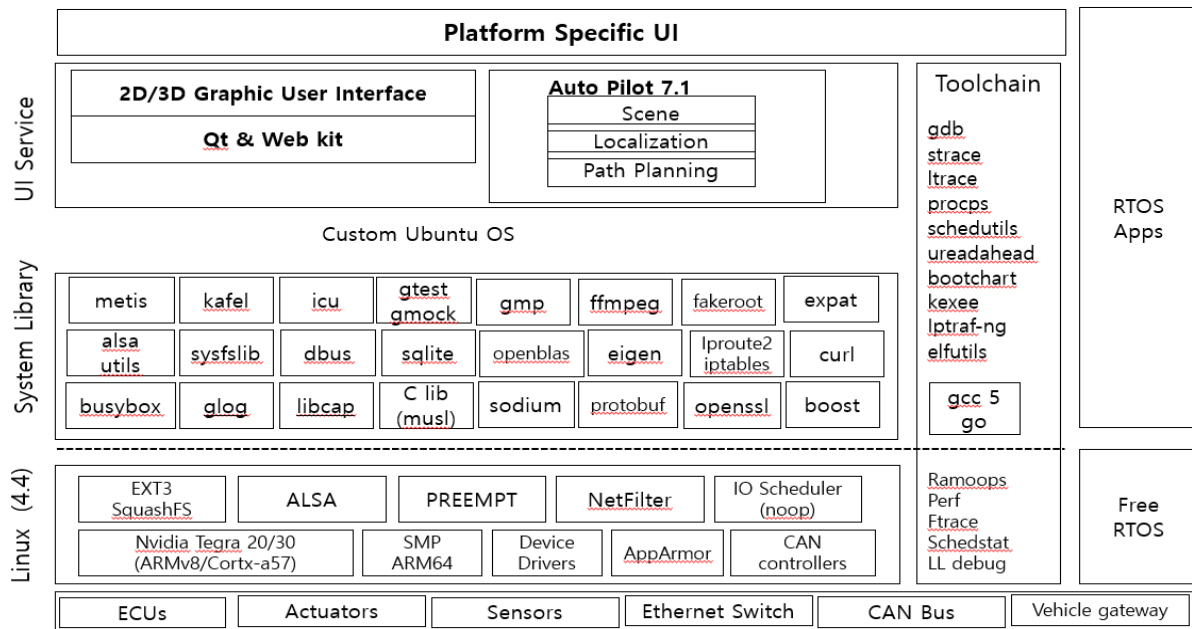

<Source : qnx.com>
Figure 3. Internal structure of QNX operating system

Tesla is a leading automobile company in the electric vehicle market. Tesla has recently been accelerating the development of systems and software for autonomous vehicle environments. The functions that control the Tesla car are executed in the Media Control Unit (MCU). The functions controlled by the MCU are opening windows, setting the vehicle speed limit, and adjusting the position of the side mirrors. The operating system (OS, kernel) version for

controlling these MCUs uses the Linux version.

Tesla has built its own operating system platform for self-driving cars. The advantage of the Tesla software platform is that it is designed to make software upgrades easy. Through the development of software technology based on autonomous driving, users can conveniently use the car. Infotainment functions are also provided centering on these platforms.
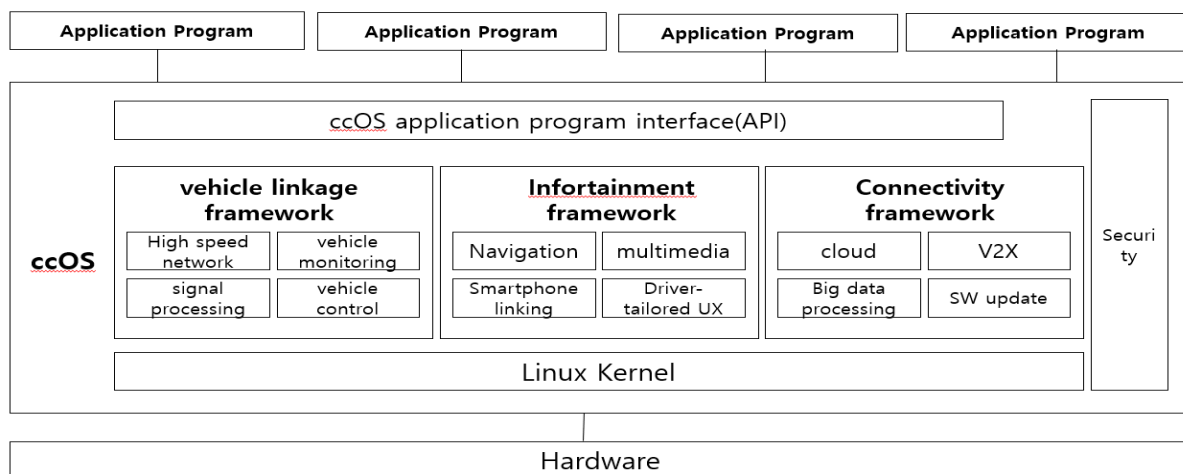

<source:https://blog.naver.com/PostView.naver?isHttpsRedirect=true&blogId=invain&logNo=221341616888>

Figure 4. Internal structure of Tesla autonomous vehicle operating system

Hyundai Motor Group is developing and using its own operating system in connection with autonomous vehicle technology. Hyundai Motor Group is developing its own Connected Car Operation System (ccOS) to secure vehicle software competitiveness in line with the increasingly important automotive software technology.

ccOS, developed by Hyundai Motor Group, is based on Linux and is used as a core operating system for vehicle control by being installed in not only infotainment systems but also autonomous vehicles.
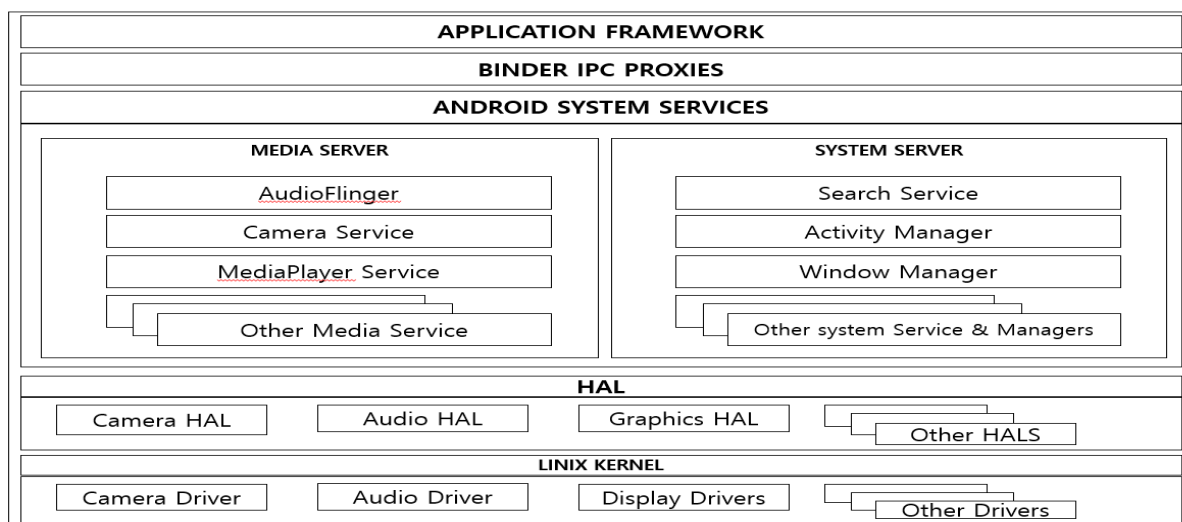

<Source : Hyundai Motor (https://www.hyundai.co.kr/story/CONT0000000000016049) [8]>

Figure 5. Internal structure of Hyundai Motor's autonomous vehicle operating system

Volkswagen is also accelerating the integration of digital technology into cars. In particular, it plans to develop and operate its own VW.OS in connection with autonomous vehicles. Volkswagen recently created the Car Software organization to develop its own software. It has a structure that creates a single platform and integrates and applies it to various types of vehicles.

Apple is the leading technology holder in smartphone technology. Apple are spurring the development of autonomous vehicle software and autonomous vehicle operating system technology by utilizing the apple smartphone software technology. Apple wants to make an operating system that perfectly handles everything in an Apple car, from infotainment and navigation to autonomous driving. It seems to adopt a centralized management method similar to Tesla for this Apple Car system function.

Toyota is developing its own in-vehicle software. This software is being developed as a module that can be installed regardless of vehicle type. This software is intended to be used for navigation as well as vehicle powertrain control. Toyota is also participating in the Linux-based Automotive Grade Linux (AGL) consortium.

<source : https://developers.google.com/cars/design/automotive-os?hl=en>
Figure 6. Internal structure of Google Automotive operating system

In order to provide such a convenient car environment, operating system software development has resulted in various problems. Among them, it is a software security problem for automobiles. These security issues are also an area that needs to be developed in conjunction with the development of operating system software.

CONCLUSION

Autonomous vehicle technology is advancing rapidly. Self-driving cars are making people's lives more convenient. In this paper, among various technologies required for such autonomous vehicles, we have looked into operating system technology trends.

The development of autonomous vehicle operating system technology is a core technology that is developed not only by automobile manufacturers but also by IT-related companies. QNX is an autonomous vehicle operating system. The QNX operating system has slimmed down the kernel functions. And, it provides RTOS function. Tesla's autonomous vehicle operating

system adopts a centralized approach that reduces the number of ECUs. Hyundai Motor Company provides ccOS based on Linux kernel. Volkswagen can be used flexibly for all types of cars regardless of car maker. Apple also offers centralized control. And, it is being developed so that it can be used in an Apple car. Toyota is developing its own operating system and is also participating in a Linux-based consortium. Google is developing technology to become a strong player in autonomous vehicle software through Android Auto.

Autonomous vehicle-related operating system technology development is being developed not only by automakers but also by IT software companies. As a result of these technological developments, it is expected that autonomous vehicles that can be operated safely will be completed and will provide convenience to human life.

REFERENCES

[1] RT solutions Inc., Introduction QNX, www.rtsolutions.co.kr/kr/sub/qnx/introduce.php

[2] Lee Sang-min, "Electric Vehicle Autonomous Driving Technology Trend", The world of electricity by the Korean Society of Electrical Engineers, vol. 69, no. 5, 2020.05.

[3] Seunghwan Lee, "Automobile vs. IT Big Tech Prelude to 'Hundred Years' War'!", Daishin Securities Industry Analysis Report, 2021.02.24.

[4] Joochan Son, Jeongdan Choi, "Autonomous vehicle system technology direction and challenges", Information and Communication of the Korea Telecommunications Society, 2018.05.

[5] Yong-Hoon Kim, Hyun-Goo Kim, "Self-driving car development trend", Information and Communication of the Korea Telecommunications Society, vol. 34, no.5 2017.04.

[6] Park Jin-hyung, "Special Report: Automobile OS warfare to reduce external dependence through in-house development", electronic newspaper, 2022.02.08.

[7] Jang, Seung Ju, "SW technology trends related to autonomous vehicles", Information and Communications Magizine, vol. 33, no. 4, pp. 27-33, 2016.

[8] hyndai motor group tech, "Connected Car Service", https://tech.hyundaimotorgroup.com/kr/mobility-service/connected-car-service/, 2022.08.22.

[9] LIFE STYLE, Operating system attracting attention in the era of autonomous driving, https://halla-dhub.tistory.com/101, 2020.09.20.

[10] Oh Min-hyuk, "Connected car OS development machine laying the foundation for SDV", https://www.hyundai.co.kr/story/CONT0000000000016049, 2022.03.17.