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DEFINING ROLE, ITEMS, AND ACCURACY LEVEL OF HIGH PRECISION ROAD MAP FOR AUTONOMOUS DRIVING

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ABSTRACT

'High Precision Road Map' can support autonomous driving. It includes lane information, road sign information, and road facility information in addition to information of existing ADAS map. In other words, it means map that autonomous driving car enables a certain level of driving with map only.

We judged two things, the autonomous driving car requires to the High Precision Road Map.

First, "Where is the lane?" The area where the vehicle can be operated is divided to display the driving range of the vehicle on the map, and the position of the vehicle is defined by the lane. Second, "What are the operating rules?" Autonomous driving should be carried out in accordance with the principles set forth by laws and regulations, such that vehicles move the roads.

Based on these principles, the autonomous driving research trends in Korea and the service requirements of large scale road map presented in Japan are summarized and map building items are selected and their accuracy levels are presented.

Key Words: Autonomous Driving, Road Map,

Introduction

Google, the US IT Company, launched the Google Self-Driving Car Project in 2009 and began developing autonomous vehicles. It has obtained the first autonomous vehicle test license in Nevada in May 2012, since then it has been testing 1.5 million miles (approximately 2.4 million km) across the United States. Google, a non-automotive company, is at the forefront of autonomous driving in the less than a decade of the world's leading automobile manufacturers, with Google Maps, an electronic map that virtually supports autonomous driving. Existing automakers who have been focusing on automobiles have researched autonomous vehicles in the form of more advanced driver assistance systems. On the other hand, based on the huge amount of data they have accumulated, Google was able to get out of the car-centered thinking and challenge the 'map-driven autonomous driving', which could lead to the top of the autonomous driving range.

Three major German automakers, Daimler AG, BMW AG and Audi AG, which have been stimulated by Google's move, took over ‘HERE’, a mapping service of Nokia. HERE has a map of more than 200 countries around the world and provides voice-assisted navigation to 94 countries, with 33 countries providing real-time traffic information services. It is a map service that bisects the navigation market along with TOMTOM of the Netherlands. The acquisition of HERE by automobile manufacturers is a representative example of their recognizing the importance of maps in autonomous driving.

Japan recognizes the importance of maps in autonomous driving and makes various efforts at the national level. While the above-mentioned examples of the US or Europe are dominated by private companies, Japan is a representative example of the government leading. The National Institute for Land and Infrastructure Management (hereafter NILIM) under the Ministry of Land, Infrastructure, Transport and Tourism of Japan (hereafter MLIT Japan) has completed the requirements for large-scale road maps that can support autonomous driving, provision services, construction items, accuracy, and renewal. What is more, the ‘Dynamic Map Construction Examination Consortium’, which consists of six road map related companies, such as Mitsubishi Electric, Pasco, to utilize the ‘Large Scale Road Map’, has been reviewing the dynamic map cooperation area. Based on the achievements, we will work together with nine automobile manufacturers such as Toyota and Nissan to standardize the data specification and construction method for the actual operation of the dynamic map on the national roads and roads, Determine the method of maintenance, coordination with relevant public institutions, and promote international cooperation. At the same time, we established 'Dynamic Map Based Planning Co., Ltd.' in June 2016, which is entrusted by the Cabinet Office to all aspects of dynamic maps, including commercialization based on continuous maintenance and updating of maps.

On the other hand, in Korea, efforts are being made to accelerate the commercialization of autonomous vehicles and to grow into future industries under government initiative in order to cope with the development trend of future global automobile. In May 2015, the government decided to commercialize autonomous vehicles by 2020 in cooperation with ministries in the "Third Regulatory Reform Ministerial Meeting" in order to improve the level of traffic safety in Korea and to develop it as a future growth engine. Through ‘Expansion of Infrastructure to Support Autonomous Driving’, which is one of the three core directions of the policy, ① development of satellite navigation technology for vehicle location, ②production of precise digital map capable of lane classification, ③expansion of road infrastructure, and allocation of communication frequency are being pursued to catch up the technology level of advanced countries.

Accordingly, the Ministry of Land, Infrastructure and Transport (hereafter MLIT) commenced the R&D project 'Development of Cooperative Automated Driving Highway Systems’ in July

2015, and notified the 'Regulations on Safety Operation Requirements and Trial Operation of Autonomous Vehicles' in August. In October, some sections of Expressway in Seoul Metropolitan area and the National Highways were designated as the autonomous vehicle test sections. In February 2016, the sections were opened for test operation. At the same time, 'National Geographic Information Service(hereafter NGII)', a governmental organization that manages the production, modification and renewal of National Digital Topographic Map including the national basic map, which is the basis of national spatial information, is designated as 'the precision map building organization for supporting autonomous driving'. In addition, the NGII was also responsible for building the high precision road map required by 'Development of Cooperative Automated Driving Highway Systems' R&D project hosted by the MLIT and the Korea Agency for Infrastructure Technology Advancement(hereafter KAIA). To this end, the NGII has coordinated with related departments and related organizations on major issues related to map accuracy. The NGII built a pilot map for the autonomous driving test section designated by MLIT in the second half of 2015. The map was constructed experimentally. In addition, NGII has carried out studies to establish the foundation for the high precision road map construction which includes the contents of the map and it accuracy as well as framework for future construction plans. The purpose of this paper is to define the role of the high precision road map and discuss the contents, and the accuracy level of the high precision road map.

2. Roles and Functions of High Precision Road Map

High precision road map is a new concept electronic map which is different from existing navigation map or node-link map. It is a map that provides various information necessary for automobile operation based on precise three-dimensional position information including accurate car information. For example, detailed road information such as the position of a traffic light, the position of a stop line, whether vehicles can change the lane, whether the intersection is allowed to turn left are provided. Attributes such as classification, rotation regulation, intersection name, traffic light, and name of area are given to the node, and attributes such as road type, traffic method, number of lanes, facility and road number are given to the link. The lane guidance for turning at the intersection is made, but this does not include the individual lane-specific attribute information in the link itself, and guidance is provided regardless of the lane where the vehicle is located. In addition to the navigation guidance information, curvature and gradient information of the road was added to ADAS map which upgraded this navigation guidance one step further. The high precision road map covered in this study is a map that can support autonomous driving. It includes lane information, line information, sign information, and road facility information in addition to the existing ADAS map information. In other words, the high precision road map means map that autonomous driving car enables a certain level of driving with map only.

To sum up, the most important difference between the high precision road map and navigation maps is whether the vehicle can travel without leaving the lane, change the lane if necessary, and whether the vehicle simply runs in the link unit road section without lane separation.

In Japan, the NILIM, which conducts research for the MLIT Japan, recognized the necessity of large scale road map, same meaning with the high precision road map, and performed the related research in advance Korea, and suggested the role of the large scale road map through analysis of service requirements of map for autonomous driving.

Table 1 Requirement list of driving support system using large scale road map

Classification	***Requirement***
Vehicle Travel Control (Horizontal Direction)	**Maintaining lane keeping** with small radius of curvature
	Lane keeping in complicate shaped road
	Driving lane keeping
Vehicle Travel Control (Front-back Direction)	**Speed control** according to road shape change
	Speed control according to incidental equipment
	Speed control according to speed regulation information
Recognition of Lane Markings etc.	**Improvement recognition rate** of partition
	Recognition of entrance and exit point of tunnel etc.
	Recognition the appropriate lane dividing line in case of poor visibility
Grasp the Vehicle Position	**Recognition** the position of the vehicle using the feature on the lane
Steering Control	**Recognition** the appropriate lane dividing line when there are multiple lane markings such as merging flow

(Lane Change)	guidance line
	Recognition the appropriate lane dividing line when there are multiple lane markings on the main line or the lamp

Source : National Institute for Land and Infrastructure Management, Japan, "Cooperative Research on method of Creating and Updating of Large Scale Road Map", No.848, 2015

The authors of the study judged that the autonomous driving car requires the high precision road map as follows. ①Where is the lane? ②What is the operation rule? The first requirement is to distinguish the areas in which the vehicle can run, to display the vehicle's driving range on a map, and to define the position of the vehicle in lane level. The second requirement defines the rules and regulations that autonomous vehicles must observe during moving.

Next, in order to define the function of the high precision road map, we compared the items of the Digital Topographic Map, which is representative national(public) content in the map field, with navigation DB and ADAS map, which are private content.

Table 2 Building Items of Public and Private Maps

Public Content	***Private Content***	
Digital Topographic Map	Navigation Map	ADAS Map
Road Boundary Lines Road Center Lines Bridges Tunnels Pedestrian Overpasses	Intersection Location Road Number Type of Road Link Type Number of Lanes Road Facilities Information Safe Driving Information Variable Lane	Curvature Gradient Height Value Lane Width Driving Route Line Representative Lane Lines Road Boundary Lines

Overpasses Underground driveways Interchange Median Quarry Retaining Wall Road Cutting Side Road Embankment	Shoulder Lane Speed Limit	In and Out Crosswalk Stop Line Tunnel Sign Traffic Light Street lamp

Since the Digital Topographic Map is prepared for the national mission of SOC management, it is built around the most basic elements. On the other hand, private contents are added to and subtracted from the items to be built for each function though they are based on the Digital Topographic Map. Private content ultimately leads to an increase in content that meets the goal of profit making.

The High Precision Road Map is supposed to follow the same utilization structure as private contents, but since there is no consensus on the symbiotic balance between the basic building items provided by the public and the private maps using them, It is concluded that the most basic information-oriented construction should be done, and that the minimum unit should be constructed considering renewal from the public rather than the private sector.

3. Selection of Items for the High Precision Road Map

3.1 National Basic Spatial Information of Korea

The essential items of the High Precision Road Map were selected based on the factors necessary for the safe operation of autonomous vehicles, after analyzing the elements of the NGII so that it can be used as an important constituent item of that information.

The NGII presented the components and standard data models of the 'National Basic Spatial Information' through the 'Study on national spatial information data model and construction of pilot DB' project in 2015. In this report, the 'National Basic Spatial Information Item Scheme' is composed of four item packages: 'Natural Geography, Human Geography, Terrain Features and

Environment'. Each package includes major category, sub category, sub-sub category, and the level at which actual data is constructed is defined as the Small category. In addition, the pilot project includes five items of the National Basic Spatial Information; Traffic, Water system, Building, Elevation, Administrative boundary. Among them, the items are defined on the basis of linkage with the national node - link system for objects defined as 1:5,000 level of transport package.

Table 3 Traffic part of 'National Basic Spatial Information Standard Data Model'

Features	***Categories***			***Items***	***Rendering***
	Major	***Sub***	***Sub-Sub***		
T R A F F I C	R O A D	R O A D B O U N D A R Y	Road Boundary Lines		Lines
			Road Boundary Sides	· Administrative District Code · Phase relationship · Maximum speed limit · Minimum speed limit · Facilities Information · Street number · Name · point · End point · Packing material · Presence or absence of separation · Number of cars · Road width · One-way	Sides

				· Road name · Area	
		R O A D N E T W O R K	Nods	· Node unique number · Administrative Area Code · Name · Node classification · Number of link links · Neighbor node number	Points
			Links	· Link number · Starting node unique number · End node unique number · Administrative Area Code · Phase relationship · Maximum speed limit · Facilities Information · Street number · Name · Road classification · point · End point · Packing material · Minimum speed limit · Presence or absence of separation · Number of cars	Lines

				· Road width · One-way · Road name · extension	
	TRAFFIC FACILITIES	Bridges		· UFID · Kinds · Length · Width · Installation year · Material · River name · Integrated code · Production information	Sides
		Tunnels		· UFID · Length · Width · Height · Integrated code · Production information	Sides
		Interchanges		· UFID · Kinds · Length · Height · Passing load	Sides

			· Material · Footpaths · Integrated code · Production information	
		Ramps	· Lamp number · Administrative Area Code · Maximum speed limit · Street number · Road classification · Point · End point · Packing material · Presence or absence of separation · Number of cars · Road width · One-way · Road name · Area	Sides
		Railway Stations	· Station number	Points

3.2 Selection of Map Construction Items

Based on the 'National Basic Spatial Information', the High Precision Road Map construction items were selected. As autonomous driving research is currently in progress, the items can be added or deleted. In addition, the items have been selected with reference to the map requirements of Japan's Large Scale Road Map, which already has the advanced standards and standards.

In addition to this, we have classified macroscopic requirements of the High Precision Road Map into lane marking, road facility, and labeling facility based on "Vehicle operation section definition" and "Compliance with the operating rules on the road". The name of list was selected so as to comply with the names of the information items expressed in the manuals issued by the MLIT and the manuals of the Korea National Police Agency (hereafter KNPA) which is operating the signals and signs.

Based on the results, the consultation with the advisory committee and the consultation with the participating agencies of the existing ''Development of Cooperative Automated Driving Highway Systems' 11 basic construction items were selected (Table 4).The names and definitions of the items to be developed are based on the classification criteria of the 'Traffic Safety Signs Installation and Maintenance Manual (KNPA, 2011)', the 'Transportation Road Mark Installation and Maintenance Manual (KNPA, 2012)', and the 'Regulations on the Structure and Facilities of Roads (MLIT, 2015).

Table 4 High Precision Raod Map Construction Items and its Basis

Selection Basis		***Basic Construction Items***	
	Category	***Basic Items***	***Detailed Items***
Requirement1 "Where is the lane?" (Vehicle Operation Section Defining)	Line Marking	(1) Regulation Line	①Centerline ②U-turn Area Line ③Lane Line ④Bus only Lane Line ⑤Lane Change Prohibit Line ⑥Reversible Lane Line
		(2) Road Boundary Line	①Road Edge Line ②No Parking Line ③No Stop Line

		(3) Stop Line	①Stop Line
		(4) Lane Center Line	①Lane Center Line
	Road Facilities	(1) Median	①Median ②Jaywalking Prevent Barrier ③Opening of Median
		(2) Tunnel	①Tunnel
		(3) Bridge	①Bridge
		(4) Underground Road	①Underground Road
Requirment2 "What is the operation rule?" (Vehicle Operation Rules)	Sign Facilities	(1) Traffic Safety Sign	①10 Warning Signs ②27Regulation Signs ③23 Diection Signs
		(2) Road Marking Sign	①No Stop Area ②Leading Line ③Leading Area ④Direction ⑤Lane Change ⑥Inclined Plane ⑦Crosswalk ⑧Bicycle Crossing
		(3) Traffic Signal	①Traffic Signal

4. Accuracy Level of High Precision Road Map

For the safe operation of autonomous vehicles, the accuracy of the map should be more than a certain level. The level of representation of the High Precision Road Map must be precise enough to be able to express even the road condition Changes and lane level information. This is because the vehicle itself must be capable of driving on a lane-by-car basis through a certain level of 'autonomous judgment' without the intervention of the driver. Therefore, the accuracy of the High Precision Road Map should be higher than the current navigation maps. In this section, the accuracy level of the map is calculated to the extent that the autonomous vehicle allowed safe driving of the 'lane unit', which means the autonomous vehicle can run with keeping its running lane.

In order to determine the accuracy level of the High Precision Road Map, we examined the error that can occur in the autonomous vehicle itself and the error that should be secured on the actual road. And we also examined the accuracy level of foreign maps with precision and the allowable range of errors was calculated.

4.1 Error Factor of Autonomous Vehicle

The positioning error that can occur in the course of the autonomous driving car can be divided into the error caused by the vehicle sensor and the error of the maps which the vehicle uses. Vehicle sensor errors include errors in the vehicle GNSS error, radar and vision sensor errors that identify the location of the vehicle, and in the system that generates the position in aggregate. Precision map errors include GNSS error of MMS and collection equipment, radar point group data error, and drawing error that occurs during drawing process based on data collection results.

Based on the review of domestic road standards and vehicle structure standards, the error range of the autonomous vehicle was estimated to be safe to operate without losing the driving lane. The road standard and the vehicle structure standard are based on the minimum lane width of the road and the maximum width of the vehicle for each road category presented in the Regulations on Road Construction and Facilities Standards (MLIT, May 2015.).

Table 5 Standard of Minimum Width by Road Category

Road Category	***Minimum Width of Road(m)***		
	Rural Area	***Urban Area***	***Small Vehicle Road***

Expressway			3.50	3.50	3.25
National Highway and the others	Design Speed (km/h)	Above 80	3.50	3.25	3.25
		Above 70	3.25	3.25	3.00
		Above 60	3.25	**3.00**	3.00
		Below 60	3.00	3.00	3.00

Source: MLIT, The Regulations on Road Construction and Facilities Standards, 2015

Table 6 Maximum Width of Design Standard Vehicle

Division of Roads	***Design Standard Vehicles***	***Maximum Width of Vehicle***
Expressway and Major Arterials	Semi-trailer	**2.5m**
Minor Arterials and Collector Roads	Semi-trailer or Large Vehicle	2.5m
Local Roads	Large Vehicle or Passenger Vehicle	2.5m / 1.7m

Source: MLIT, The Regulations on Road Construction and Facilities Standards, 2015

The minimum lane width for each road is 3.00m, and the maximum width of the design standard vehicle is 2.5m based on the semi-trailer. When the semi-trailer runs on a 3.00m wide lane with shifted to one side, that side has no margin width and the other side has a margin width of 0.5m.However, the autonomous driving car can be driven by the lane center without being shifted to one side by various sensors. Therefore, when an autonomous vehicle, which can be regarded as an ideal running condition, runs at the center of the lane, there is a margin width of 0.25 m on each side. Based on this, ± 0.25m was derived as tolerance range.

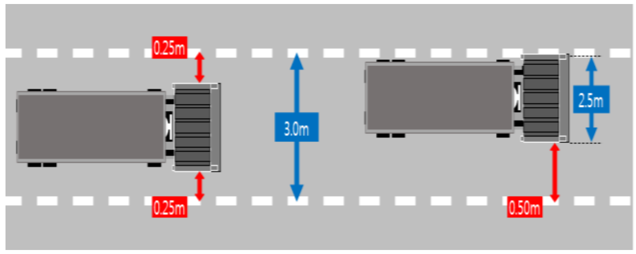

Fig.1 Side Margins of Maximum Width Vehicle on Minimum Width Road

4.2Error of Vehicle Sensor

As mentioned above, autonomous vehicles are equipped with various sensors including GNSS that can confirm their position. The Lane Keeping Assistance System (LKAS) and the Lane Departure Warning System (LDWS) are typical examples of sensors that support autonomous vehicles drive safely in lane. Both sensors recognize the lines through a camera installed at the front of the vehicle, allow the vehicle to run without leaving the lane, and alert the driver when the vehicle encounters lines. LKAS technically controls the vehicle within ± 0.10 ~ 0.15m. LDWS is a system that recognizes tires and lines, so it is relatively easy to measure and the error detection level at the present technology level is within 0.02m.

The technology of the sensor mounted on the autonomous vehicle is continuously developing, and the error of the sensor and the system is also rapidly decreasing to converge to almost '0'.Therefore, it is expected that the error of the vehicle sensor can be converged to '0' in view of the safe operation of the autonomous vehicle from the inside the lane.

4.3Error of High Precision Road Map

In Korea, in case of surveys other than basic surveys carried out by the state, municipalities, or public institutions, the 'Regulations for Public Survey' shall be followed. This regulation defines the accuracy standards for digital maps for public survey purposes as follows.

Table 7 Accuracy of Digital Map by Public Survey

Item	***Scale***		***Remark***
	1/500↑	***1/1,000 ↓***	

Standard Deviation	Flat Position		Within 0.5mm	Within 0.7mm	Road Distance
	Elevation	Elevation Point	Within∆h/4	Within∆h/3	∆h:Spacing of the Curve
		Contour	Within∆h/2		

Source: NGII, The Regulations for Public Survey, 2015

If a numerical map with a scale of 1:500 or more is made by public survey, the standard deviation of the plane position should be within 0.25m, and the standard deviation of the elevation point should be within 0.25m.

In NILIM's study, the standard scale of the Large Scale Road Map, which is the same concept as our High Precision Road Map, is considered as 1:500 level, and the accuracy of this is suggested as 0.25m of standard deviation of error. And the 'Dynamic Map Consortium' stated that the relative accuracy of maps also agreed that the standard deviation of the errors is within 0.25m through the review of 'Definition of Basic Map Requirement', Specification of Basic Map Data', 'Instruction for Writing Map Data' which assist in the automatic driving system in the 'Dynamic Map Structuring Task Form Report' held in January 2016.

In this study, the precision of the final result of the High Precision Road Map was selected as the accuracy of the 1:500 digital map of the ' Regulations for Public Survey Work'. The final result of the High Precision Road Map means the results of correcting all the errors, such as the GNSS error of the MMS, the error of the laser point group data, and the drawing process error. We can find that the selected accuracy is the same as the 0.25m presented in the calculation of the autonomous vehicle range difference.

4.4Final Accuracy of High Precision Road Map

In this study, the High Precision Road Map to support the autonomous driving vehicle should meet the accuracy of the 'Public Survey' level as shown in <Table 8>.

Table 8 The Final Accuracy of the High Precision Road Map

Scale	***Standard Deviation(m)***	
	Flat Position	***Elevation Point***

More than 1/500	Within 0.25	Within 0.25
Less than 1/1,000	Within 0.70	Within 0.67

5. Conclusions

In this study, we suggested the necessity of maps in autonomous driving through the case of foreign countries and proposed the building items and its level of accuracy of the High Precision Road Map. Based on the 'definition of the driving area of the vehicle' and the 'observance of the operating rules on the roads',[Regulation Line, Road Boundary Line, Stop Line, Lane Center Line, Median, Tunnel, Bridge, Underpass Road, Traffic Safety Sign, Road Marking, and Traffic Signal] were presented as the 11 High Precision Road Map construction items. Also the accuracy levels of the High Precision Road Map were calculated based on the assumption that the maps were newly produced. As a result of examining the errors that can occur in the autonomous vehicles and occur in the cartographic process, the error range of 0.25m was calculated, and the tolerance range of the Large Scale Road Map and the Dynamic Map of Japan was also 0.25m.It was also found that the tolerance range proposed in the 'Regulations for Public Survey'is also 0.25m.Based on these, in this study the accuracy of the High Precision Road Map was suggested to be within the standard deviation of 0.25m.

However, considering that the map must be updated quickly in accordance with the constantly changing road environment in order for the autonomous vehicle to run safely on the basis of accurate real time information is one of the requirements of the High Precision Road Map, it may be necessary to consider the error in the revision and update process. Considering this point, it is reasonable to make the accuracy of the High Precision Road Map higher than the suggested level for the new production. If the accuracy level is estimated through the more discussion on this, it is expected that the High Precision Road Map will be enough to support the safe operation of autonomous vehicles.

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