Network-Oriented Road Map Generation for Unknown Roads using Visual Images and GPS-based Location Information

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Abstract — *Car navigation systems (CNS) have become an interesting research and industrial topic due to their wide deployment. However, updating and distribution of the road map database is a complex and high cost process. In this paper, we propose a real-time map generation and updating algorithm, which fulfills or corrects the unknown road area of the conventional road map database by using global positioning system (GPS) information and wireless communication technologies. To generate the road map of unknown roads, the proposed algorithm uses road images, which can be obtained when a driver travels unknown roads. When a driver travels unknown roads, which do not appear on the map of the car navigation system, the car navigation system extracts GPS and image information of the unknown roads. Then, the car navigation system generates the road map for the unknown roads by extracting location and road information, and updates the road map database in the car. After updating the local road map database, the car navigation system updates the master road map database, which is located at the network and is distributed to other car navigation systems. Thus, the road map database provider can update the road map database of other car navigation systems, which share the same master road map database. The proposed algorithm provides an efficient updating process of the road map database with a simplified process and reduced time for unknown road areas*[1].

Index Terms — Car Navigation System, Map Updating, Detection of Road Edge, Global Positioning System (GPS)

I. INTRODUCTION

A car navigation system is defined as a device which helps drivers to drive comfortably and safely by providing various travel-related information, such as destination directions, road maps, present road situations, weather conditions, vehicle speed and travel obstacles. The driver defines the destination before he departs from the source. Then, the CNS continuously informs the driver with road information such as direction, speed limitation, and obstacles based on the road map database. Thus, the CNS can support the driver until he arrives at the final destination safely and efficiently. Also, the CNS can provide preferred directions based on various conditions given from the driver such as expressway preferred, local road preferred, shortest way preferred, etc.

Actually, the conventional CNS for general cars was derived from the military purposed navigation devices which provide road information for military ships and air flights. Currently, the CNS is considered a core device to enable intelligent transport system (ITS). Thus, international studies and standardization efforts for CNS are widely in progress in certain areas, especially for the management and generation of road map databases and related information. Among related activities, the EDMap project by the U.S. Department of Transport and NextMap project of the European Union are the most famous projects related to CNS [1][2][3].

CNS consists of user terminal equipment, GPS receiver, road map database, user application software, wireless communication module, etc. The GPS receiver receives location information from the satellite and transfers the current position information of the vehicle to the user terminal equipment. Then, user application software provides directions by using the current position, road map, and direction information for the desired destination. According to wireless communication support, conventional CNSs have started to utilize wireless communication capability, which provides communication technologies such wideband-CDMA (WCDMA), High Speed Packet Access (HSPA), and mobile-WiMAX. Furthermore, by using wireless communication, the CNS can communicate with a central server to receive current road information such as accidents and congestion. Also, the CNS can display the real-time road status information to the driver. However, if we consider the road map generation and updating process, wireless communication technology is not popular for road map generation and updating processes. Thus, an updating cycle of a road map database is different according to the road map update frequency of the road map database provider and user. If a user wants to update the local database at the user terminal equipment based on the master database at the provider's side, the user should be connected to the Internet and manually check the update status of the master database. Thus, the road map generation and updating process is not an autonomous process, and real-time road map generation and updating procedures are not supported. At present, CNS users should download the updated road map database by using a computer and memory card to store the updated road map, and then attach the memory card to the CNS. This process is complicated and inconvenient.

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Conventional studies on CNS are largely divided into two fields - position detection and automatic updating of the road map database. According to studies on position detection, dead-reckoning, map-matching, and its hybrid algorithm are the most famous types [6][7][8][9][10]. In this case, point-to-point matching, point-to-curve matching, and curve-to-curve matching are famous algorithms proposed for map-matching [8][10]. According to the automatic updating of the road map database, the map reverse updating algorithm is proposed to update the road map database using a bulky volume of raw GPS trace data [4]. In this algorithm, cars gather GPS information for unknown roads on additional non-volatile memory. Then, a new road map is generated based on this raw GPS road information.

However, the map reverse updating algorithm has several problems. First, it requires a large amount of nonvolatile memory at the user terminal device to store GPS information for unknown roads. Second, raw GPS information should be transferred to the map database provider manually, which means the user should transfer the non-volatile memory from the CNS to another computer to upload the raw GPS information. Subsequently, the user can upload raw GPS information to the map database provider through the Internet. Third, updating the local road map database at the user terminal equipment is also complex and inconvenient. This requires the same manual process using non-volatile memory from the CNS, checking for new map availability, new map downloading, updating of the local road map database, and finally reattaching the memory to the CNS.

To solve these problems, we propose the new road map generation and updating method. The proposed scheme includes 1) the image processing phase to extract the new road information and generating the new road map for the unknown road, 2) distribution of the master road map database through the wireless connection, which means the CNS at the vehicle uploads and updates the master road map database using wireless communication technology, 3) updating the local CNS through synchronization with the updated master road map database, and 4) an additional process to synchronize the updated road map database with adjacent vehicles.

In this paper, we introduce general algorithms for the extraction of road position, updating of road information, and updating cycle of the map database in Section 2. Section 3 describes the proposed network-oriented CNS to generate and update data of unknown roads. We evaluate the performance of the proposed algorithm in Section 4 and we conclude this paper in Section 5.

II. Conventional Road Map Database Generation and Update Technologies

A. Position Detection-based Road Network Update

The position detection is the most fundamental and important calculation technology in a CNS. Depending on the accuracy of the position detection, the CNS measures the current position more exactly and provides the correct search path. Conventional approaches are dead-reckoning, map-matching, and a hybrid algorithm.

- Dead-Reckoning (DR)

DR is a calculation by way of self-contained navigation. It is a method to determine current position through detection of the traveling distance and direction using the built-in distance and direction sensors of vehicles.

- Map-Matching

At longer distances or driving time, assumption coordinates detected by the DR method have many sensor errors. As a result, the actual position is displayed on the map incorrectly; map matching corrects this error and modifies the current map position. In other words, the basic principle of map matching corrects cumulative error and marks the current position on a digital map by comparing the road shape of a digital map read from the map database with traveling trajectory of assumption coordinate detected by dead-reckoning.

- Hybrid Method

The hybrid method uses speed sensors, direction sensors, and GPS to measure the current position. The shortcoming of the GPS method is that it is difficult to calculate the current position in a place where electric waves do not reach, and the shortcoming of dead reckoning is cumulative error. So, to overcome these shortcomings we use the hybrid method.

B. The Currency of Road Networks

The road network currency describes how fast and how exactly the road map database reflects newly opened or closed roads. In the case of most road map databases in South Korea, the currency of national capital region roads, freeways, and state roads have reached an equalized degree. However, in the case of a newly built city or local roads, due to the low amount of vehicle travel, currency still has a lot of regional variation. When we discuss the CNS background, whether it is strong or weak in a specific region, the portion and accuracy for unknown roads are presented as evidence. Fig. 1 shows the unknown roads of a specific region [5].

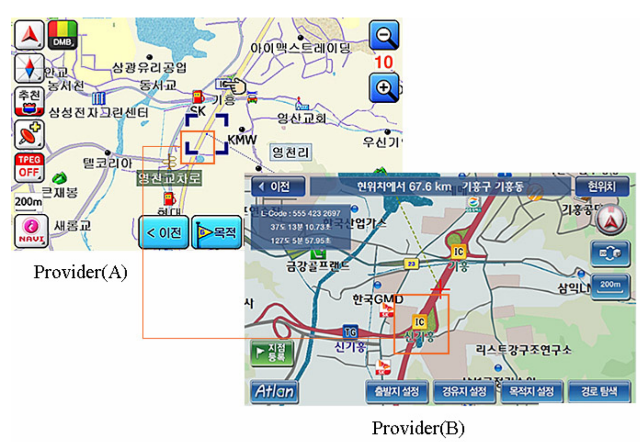

Fig. 1. Currency Difference for CNSs

According to Fig. 1, an interchange (IC) of an expressway was temporary opened on January 28, 2008. The CNS from provider B was updated, whereas the CNS from provider A was not updated by March 2008. If we compare the two maps above, provider B's map shows new road information in more detail, whereas provider A's map does not show the new road information. Therefore, provider B offers the updated map information more frequently, and the currency of provider B's map is superior to that of provider A.

C. *Actual Traveling Test*

Usually, new information for unknown roads made by new city construction and secondary road construction is updated through periodic actual traveling tests, or through the statement of driver on an internet notice board of the map database provider.

Actual traveling testing is a method in which the road map database provider travels the entire country in vehicles (probe cars), which are equipped with measurement devices such as the original map, notebook, and differential-GPS (DGPS). The devices in the probe car collect various data and verify previously collected road map information. Fig. 2 shows the road map database provider's map updating procedure from driver statements or actual traveling tests.

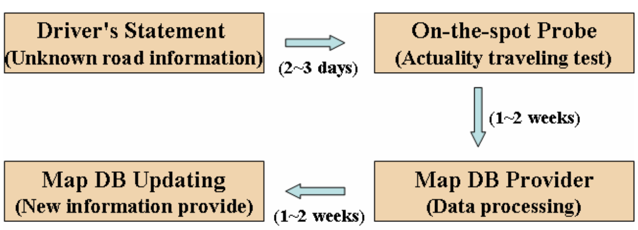

Fig. 2. Road Map Database Updating Procedure based on the statements of drivers or actual traveling tests

Due to this long-term process, the new information of unknown roads requires an un-synchronized period for the map provider to update the local road map database at the user terminal. In general, it takes one month at minimum. The currency of CNS is an important element, and a fast updating cycle is necessary for the safety and efficiency of driving. Therefore, research on real-time update methods for road map database is required. Table 1 shows the road map database updating cycles of a representative road map database provider in South Korea.

TABLE 1
ROAD MAP DATABASE UPDATING CYCLES OF REPRESENTATIVE PROVIDERS IN SOUTH KOREA

Road Map Provider	Road Map Updating Cycle
ATLAN	1 month
INAVI	2 months
MAPPY	1 month
GINI SF	1 month
ROUSEN	1 month

D. *Vehicular Networks*

Currently, on-vehicle wireless communication methods are widely deployed using high speed wireless broadband technologies, such as HSPA and mobile-WiMAX, in view of technologies, standardizations, and commercial products. Most applied areas of on-vehicle wireless communication include congestion control for heavy roads [11], road safety enhancement [12], and optimized road direction service based on current road conditions such as an accident, congestion, and other periodic events [13]. Recently, the Vehicle Infrastructure Integration Initiative (VII) project has been supported by the U.S. Department of Transportation (US DOT) [14]. The goal of this project is to enable cars with wireless communication devices and support vehicle-to vehicle, and vehicle-to-infrastructure communication. Thus, a national ITS network is being considered. Furthermore, vehicles achieve the collection and reporting of information, and then reutilize this information through the national wide ITS network. VII adopts vehicle-to-vehicle (V2V) communication methods and the dedicated short range communication (DSRC) technology based on IEEE 802.11. DSRC technology can be adopted in vehicle-to-infrastructure (V2I) communication to enable the communication between vehicles and infrastructure equipment (ex: traffic lights) of the road network. Simple information exchange can be achieved through V2V and V2I. Through the use of 3G and 4G wireless broadband communication technologies such as WCDMA, HSPA, long term evolution (LTE), and mobile-WiMAX, CNSs can also achieve high speed information exchange with the Internet. In Europe, the European Conference of Transport Research Institutes (ECTRI) project has been in progress since 2003. ECTRI is divided into 12 research areas, which include the research on intelligent vehicles [15]. In the ECTRI, they consider the traveling path service application for vehicles with wireless communication technology.

Thus, it is possible that the CNS in the car can transfer the locally updated road map information to the map database provider, and the provider reflects the change to the master database in real time by using wireless broadband technologies and standard road map database update procedures. In other words, vehicles which support 3G and 4G mobile communication technology can achieve the road map information updates in a convenient time and place.

III. ROAD MAP DATABASE UPDATING FOR UNKNOWN ROADS

A. *Real Time Road Map Generation and Updating Procedure*

Fig. 3 shows differences between the conventional and proposed real time road map database updating methods for unknown roads. The proposed method divides its local road map database into a user area and a provider area. Then, it updates both the local road map database and provider's master database in real time using 3G and 4G mobile communication technology.

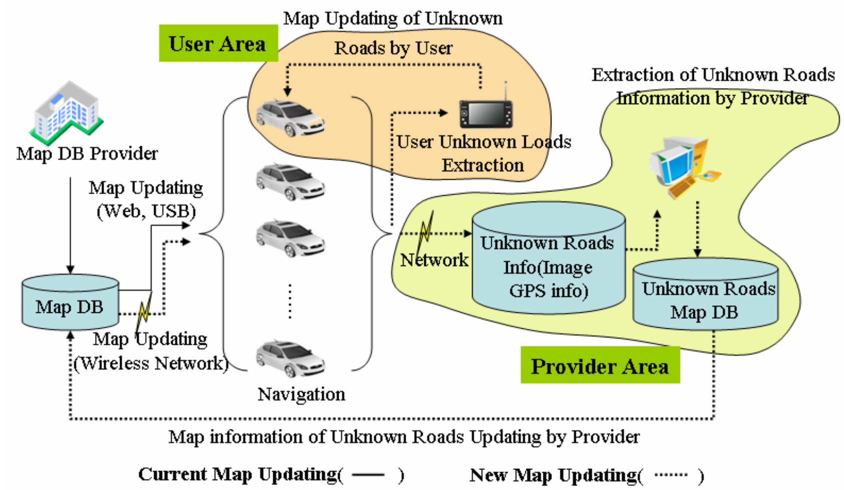

Fig. 3. Conceptual Procedure for Road Map Generation and Updating for Unknown Roads

B. System Architecture for Unknown Roads Information Extraction and Road Map Database Updating

Usually, a car travels over a road, except in the case of a wide parking lot. A driver can travel to the destination by using a CNS's direction service where the driver defines the destination before he/she begins to drive, or the driver can travel to a destination without direction service. A driver can travel to his/her destination using unknown roads, which do not appear in the CNS's road map database. In this case, the CNS cannot provide information for a new path, and the driver may not properly navigate the unknown roads. In such cases, the driver navigates the unknown roads by information of road signs or his own judgment. Many drivers can travel to a destination using unknown roads but, because information of unknown roads is not updated to the CNS's map information in real time, there is a strong possibility that many drivers will experience trial and error navigation. Furthermore, according to the conventional procedures described in Fig. 2 and 3, since it takes at least one month to update and distribute the master road map database, the driver must navigate unknown roads for a long period of time. However, if the driver travels unknown roads with 3G and 4G mobile communication technology-enabled CNS (Network-oriented CNS – NCNS), and the NCNS supports a built-in camera to extract the road image information of unknown roads with GPS-enabled location information, we can enhance the road map generation and update procedure efficiency. Fig. 4 shows the overall operation scenario of the proposed approach.

First, NCNS extracts and generates the road map for the unknown roads that a driver experienced, then the driver evaluates the information which is extracted at one's own NCNS in real time and updates his/her local road map database located at the NCNS in real time. Second, drivers transfer generated road map database information for an unknown road to a road map database provider through wireless communication network. Then, the road map database provider analyzes the received road map database for unknown roads with GPS position information, and road image reliability. After this, when the received road map database is suitable for map information, the provider updates the master road map database and attempts to update the entire NCNS. The updated master road map database is transferred to NCNS in real time through the wireless communication network.

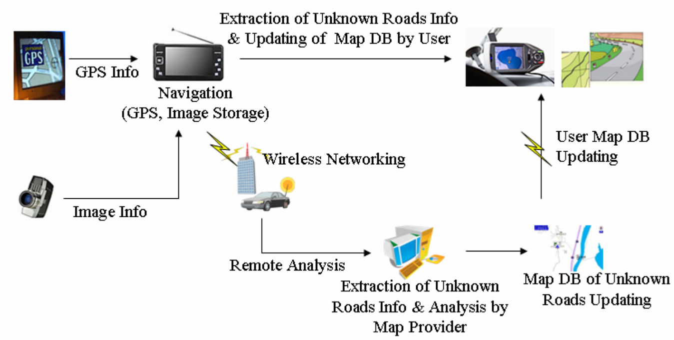

Fig. 4. Proposed Architecture of Road Map Database Updating for Unknown Roads

Fig. 5 shows the internal architecture of NCNS used to update road map databases in real time. Information of unknown roads is extracted and combined with GPS position information for the roads. For this, road images, which are extracted by camera with a digital road map (DRM), are created at the NCNS.

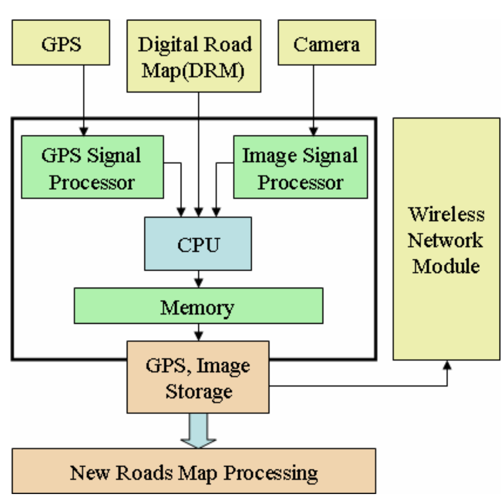

Fig. 5. Internal Architecture of NCNS

Fig. 6 shows the flowchart for updating the road map database of NCNS for unknown roads, the technology which is proposed in this paper.

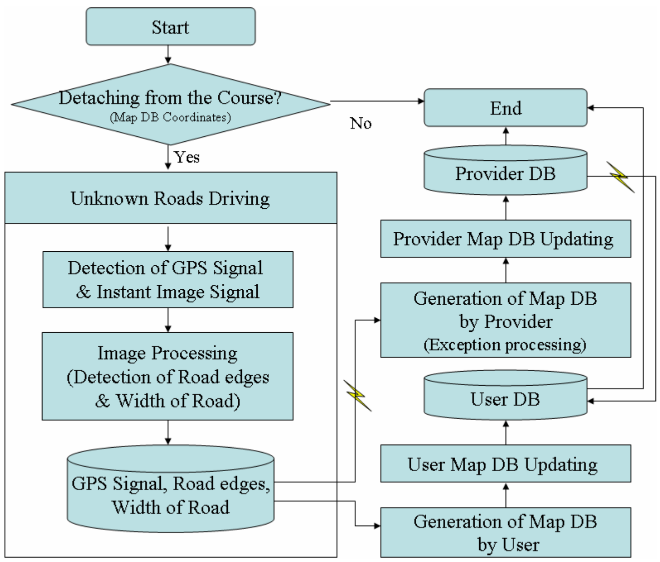

Fig. 6. Flowchart of Road Edge Detection and Road Map Database Updating

C. Extraction of GPS Position

NCNS stores all GPS information for unknown roads that are received by the driver traveling those roads. In this case, GPS information is automatically stored within the NCNS in two to three seconds, like a black box system of vehicles, to avoid the accuracy error of GPS information. For example, consider the case of a driver using unknown roads to travel from position (A) to position (B): 1) During travel, a distance interval between measured GPS position coordinates and road position coordinates of DRM is measured [ex: position (A)], if the distance interval becomes more than set thresholds, it is estimated that the driver is traveling unknown roads from position (A). 2) Based on the current position coordinates, the NCNS stores all position coordinates continually during travel, including the stored GPS information, within two to three seconds.

Furthermore, while traveling, if the distance interval between a measured GPS position coordinate and DRM road position coordinate [ex: position (B)] becomes less than the set thresholds; 3) It is estimated that the driver is traveling to position (B) using unknown roads. 4) Lastly, the stored GPS information is used to estimate the unknown road coordinates, by the NCNS road map database for unknown roads. This time, due to the possible error in GPS position, we can use the map matching method, which uses mass GPS trace data [4]. At the same time, if the traveled road is determined to be an unknown road, road images collected while traveling are stored.

D. Extraction of Road Edges after Processing of Instant Road Images

The images of unknown roads are detected using a built-in camera in the CNS during travel. Through GPS tracking, if a driver travels a road that is not stored in an existing road database, the NCNS estimates that the driver is using an unknown road, and images of the road are stored automatically in an image box of the NCNS. The instant road images can be divided into three cases, as shown in Fig. 7.

- First, the case of traveling to unknown roads from existing roads, which have supplied position information. (Detaching of GPS position).
- Second, the case of traveling to an existing road from unknown roads. (overlapping of GPS position).
- Third, the case of continuously traveling unknown roads.

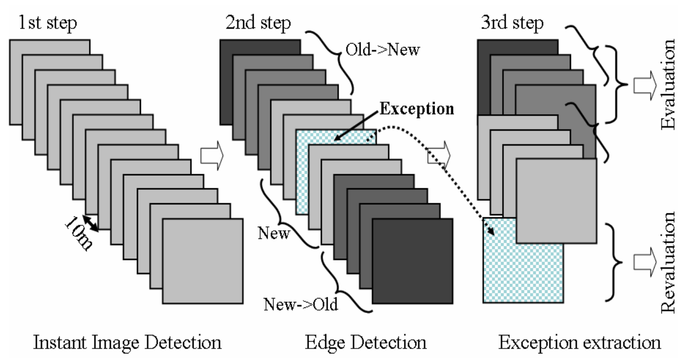

Fig. 7. Instant Road Image Storing and Processing based on Road Edge Detection

In this third case, due to the limitation of memory capacity, the NCNS cannot store all images during unknown road travel. In the first and second cases, because the location where the car first enters into unknown roads is considered the control point, NCNS stores instant images by ±5 seconds duration with 0.1 second period, once the car has entered into the control point. In the third case, because it is part of the general traveling section, the NCNS stores instant images at 10meters interval. Actually, because road map database providers do not evaluate unknown roads through actual traveling tests, it is not easy for these providers to analyze whether or not the roads are available for travel, using only the extracted information. However, the road map database provider can evaluate the validity of extracted road information with GPS position information of the location, with straight line images of the roads which can be extracted from storage via instant road images, and with the detection of road width. It is possible to measure the GPS position information of a specific navigation point; however, special processing is needed to detect the edges of roads and calculate the road width. Edge detection methods are generally used for road detection [16][17]. To decrease noise information which is caused by the many edge characteristics of roads, application of a median filter to the original image is required, along with a canny edge detector [18]. Because the road edge has a special quality of line segment, the line segment area is detected by Hough transform [19]. Also, because the area of road which is viewed from a traveling car exists in the downside area(NCNS), it is possible to evaluate the downside area of straight line segment to road area.

IV. Experimental Performance Evaluation

In this paper, we propose a method for automatic road map database generation and for updating unknown road information by using visual images and GPS location information updated during travel.

A. Extraction of Road Edges

Fig. 8, 9, and 10 illustrate the detection of line segment areas and detected road areas in stored instant road images. Because a curved road can be displayed by links of short straight lines, the curved road of Fig. 10 is detected correctly. In the figures, (a) is an instant road image, (b) is a detected edge after filtering, (c) is a detected straight line segment, and (d) is the detected road.

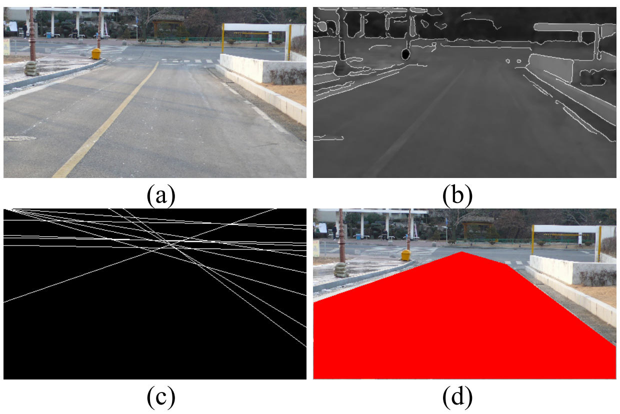

Fig. 8. Straight Road Detection Example 1

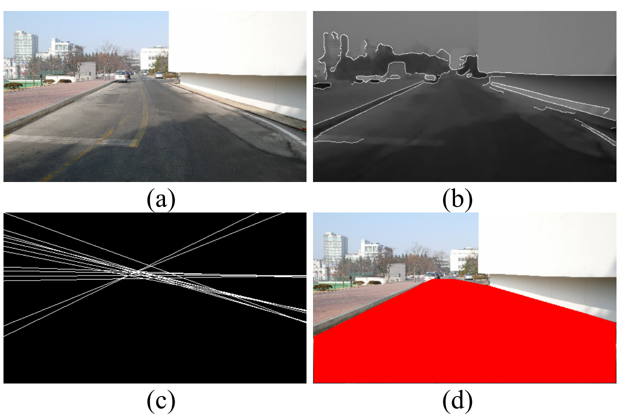

Fig. 9. Straight Road Detection Example 2

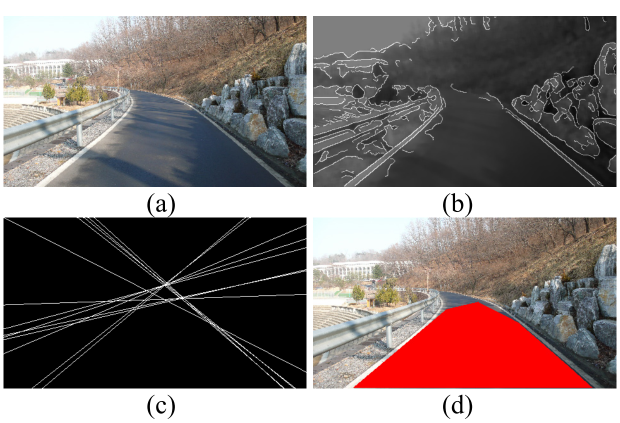

Fig. 10. Curved Road Detection Example

Fig. 11 shows the estimation of decision validity through the calculation of road width in a detected straight line segment image. The horizontal lines (H1, H2, and H3) are divided according to the distances from the fronts of the vehicles. Here, the provider measures the distance between the two intersection points of the horizontal lines (H1, H2, and H3) and detected straight line segment. If the distance measured becomes more than the set thresholds, that section is considered to be a valid road section. In Fig. 11(a), because there is no intersection point for the horizontal line (H1) and straight line segment, the provider instead measures the length of horizontal line using road width. Furthermore, because the `intersection point of horizontal lines (H2, H3) and the straight line segment are B′ and C′, respectively, the provider measures each length from the end of the left side to the corresponding intersection point (B′, C′) again using road width. In Fig. 11(b), the provider measures the lengths, A~A′, B~B′, and C~C′, which are intersection points for each horizontal line and straight line segment pairing. Fig. 11(c) denotes the same. In this way, the provider can evaluate the validity of extracted roads through calculation of road width using the detected straight line segment images and horizontal lines.

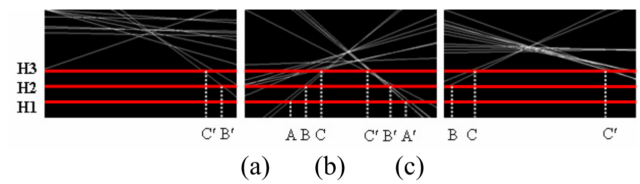

Fig. 11. Sectional Calculation of Road Width

Fig. 12 shows the calculation of average road width from a straight line segment image.

If the driver determines that the measured road width as determined by using the straight line segment was not measured accurately or that the extraction of road area using image processing was not achieved correctly it is no problem for the driver to send the update of the extracted unknown roads information in to the local road map database in the NCNS. However, from the view of the road map database provider, an additional confirmation process is required to check the validity of the generated road map database for the unknown roads. For example, if the unknown roads information transmitted through wireless network is incorrect**,** the provider needs to confirm road images manually, or through the mass GPS trace data processing method [4]. These processes require less cost and time than actual traveling tests.

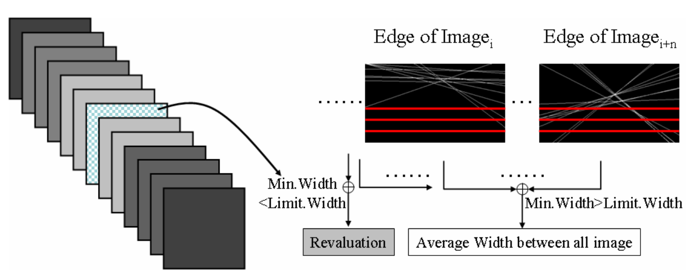

Fig. 12. Calculation of Average Road Width

B. Updating of Unknown Roads on Map Database

Fig. 13 shows the actual image of a car navigation map, which was provided by iNAVI in South Korea, and was used for the experimental performance evaluation of the proposed scheme.

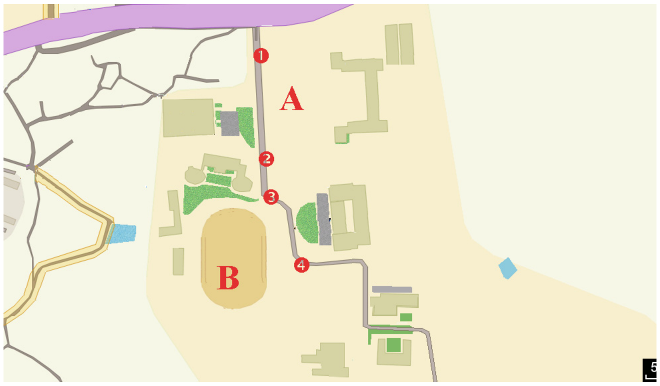

Fig. 13. Actual Image of Car Navigation Map

Currently, most car navigation maps support the concept of magnification, which provides reduction and expansion of the map. In Korea, map magnification is organized as follows: level 01 shows a map of Korea, level 02 shows the freeway center, levels 03 and/or 04 show freeways and main place-names, levels 05 and/or 06 show freeways and state roads, level 07 shows roads and villages, in levels 08, 09, and 10 it is possible to search roads and main landmark maps, levels 11 and 12 are set up based on the departure or destination position, and lastly, level 13 is used for detailed information. In this paper, we used magnification level 12. This magnification shows all buildings and road information, with settings of departure and destination available for use on the map. The lower end of Fig. 13 shows the actual distance unit.

We divided the map into two areas and evaluated data as shown in Fig. 13:

Area (A) - Traveling from position ❶(127.044255, 37.145038) to position ❷(127.044293, 37.144474), and Area (B) - Traveling from position ❸(127.044322, 37.144218) to position ❹(127.044502, 37.143799).

Table 2 shows GPS coordinates of unknown roads, which were extracted during test traveling in area (A) and area (B). Fig. 14 shows the extracted GPS coordinates of the map during test traveling.

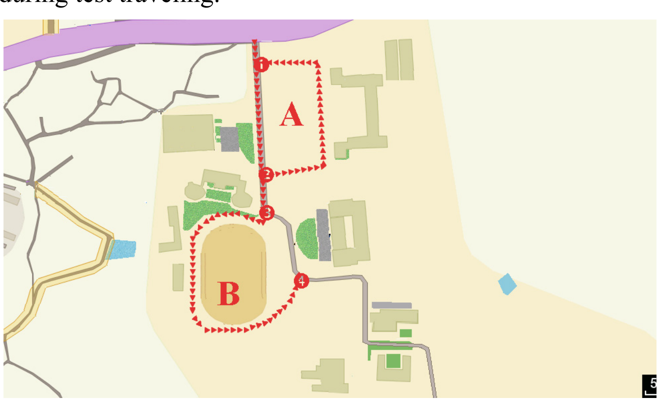

Fig. 14. GPS Coordinates of Unknown Roads on Map During Test Traveling

TABLE 2
GPS COORDINATES OF UNKNOWN ROADS

	Area	
	A	B
Coord-inates (E, N)	(127.044255, 37.145038)	(127.044322, 37.144218)
	(127.044279, 37.145037)	(127.044301, 37.144202)
	(127.044290, 37.145037)	(127.044294, 37.144190)
	(127.044302, 37.145036)	(127.044283, 37.144170)
	(127.044310, 37.145036)	(127.044262, 37.144161)
	(127.044326, 37.145036)	(127.044236, 37.144164)
	(127.044342, 37.145035)	(127.044217, 37.144170)
	(127.044354, 37.145035)	(127.044192, 37.144176)
	(127.044366, 37.145034)	(127.044169, 37.144185)
	(127.044374, 37.145034)	(127.044139, 37.144195)
	……	……
	(127.044399, 37.144474)	(127.044431, 37.143692)
	(127.044387, 37.144474)	(127.044438, 37.143706)
	(127.044376, 37.144474)	(127.044444, 37.143720)
	(127.044368, 37.144474)	(127.044451, 37.143726)
	(127.044353, 37.144474)	(127.044461, 37.143737)
	(127.044342, 37.144474)	(127.044468, 37.143748)
	(127.044331, 37.144474)	(127.044471, 37.143759)
	(127.044319, 37.144474)	(127.044485, 37.143776)
	(127.044304, 37.144474)	(127.044492, 37.143784)
	(127.044293, 37.144474)	(127.044502, 37.143799)

Fig. 15 shows the updated road map database at the NCNS.

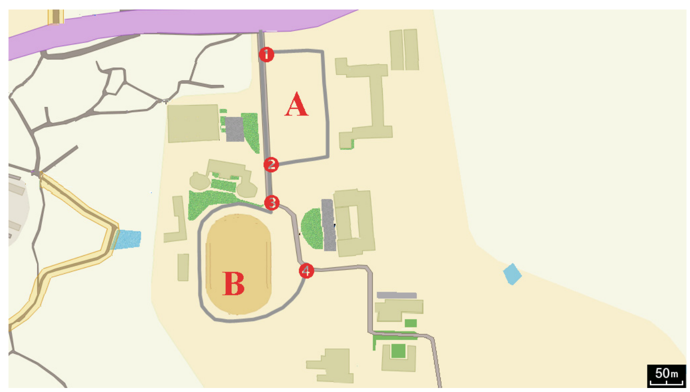

Fig. 15. Final Updated Map of NCNS

V. CONCLUSION

This paper proposed an automated road map database generation and updating architecture in real time by using GPS information and detection of road images while traveling unknown roads. When a driver travels unknown roads that do not appear in the car's navigation map, the network-oriented car navigation system can extract GPS information and image information of the unknown roads effectively. Subsequently, extracted information is used to update the local road map database in the NCNS, then that the updated road map for unknown roads is uploaded to the road map database provider to enhance the master road map database. For this, wireless communications technologies are used to transfer updated information of unknown roads to the provider's map database. Current map information updating through test traveling requires much cost and time. However, the proposed scheme could update unknown road information automatically to the map within the network frame and vision in real time for less cost and time.

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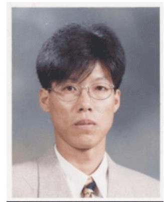

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