Map Generation and Updating Technologies based on Network and Cloud Computing: A Survey

SeungGwan Lee[1] and Sungwon Lee[2]

[1]*Humanitas College, Kyung Hee University, Korea*
[2]*Department of Computer Engineering, Kyung Hee University, Korea*

[1]*leesg@khu.ac.kr*, [2]*drsungwon@khu.ac.kr*

Abstract

Navigation systems have become an interesting research and industrial topic due to their wide deployment. The method of updating the map database (DB) with previously unknown map information has become an important factor in navigation system design. At present, multiple map DB providers maintain their own datasets and work to reduce unknown map information in only their proprietary maps. Map updating systems can generally be divided into two fields: position and traffic sign detection, and network and cloud based map generation and updating. This paper introduces the main difficulties associated with determining and updating unknown map information and briefly surveys the state-of-the-art technologies in this field. Further discussion on potential trends in the development of unknown map information is also provided.

Keywords: *Navigation System, Map Updating, Map Generation, Traffic sign Detection, Cloud Computing, Open Map, Terminal Mode*

1. Introduction

A navigation system is defined as a device which enhances driver comfort and safety by providing various travel related information, such as destination directions, road maps, present road conditions, vehicle speed and travel obstacles. The user defines the destination before departing from the source and the navigation system then continuously provides the user with travel information, which is extracted from a road map database (DB), until he arrives at the final destination safely and efficiently. Navigation systems can also provide directions based on various user-specified conditions, such as preferences for travel by expressways, local roads or over the shortest travel distance [1]. Due to the variety of constraints and preferences embedded in a navigation system, the method of updating the DB on which the system is based is critical to system performance.

Due to their growing feature list and increasingly wide deployment, navigation systems have become an interesting research and industrial topic. Especially, the updating and distribution of the map DB is a complex and high-cost process worthy of additional study. Real time map updating methods, namely those using wireless communication technologies, have not been widely considered for map generation and updating processes. Thus, the updating cycle of a map DB presently depends on the frequency at which the map DB provider and user update their map DBs [2, 3].

Usually, if a user wants to update the map DB of his terminal equipment to match the provider's master map DB, the user connects his equipment to the internet and manually checks its update status relative to that of the master map DB. Thus, the map generation and updating process is not automated and real-time map generation and updating procedures are not supported. Navigation systems presently require a user to download updated maps to a memory card, using a computer, and then reattach the memory card to the navigation system. This complicated and inconvenient process of updating flash memory can take up to ten minutes, and the quality of the resultant data is entirely reliant on the accuracy of the latest DB update from the map provider, and the extent to which it captures previously unknown map information [2, 3]. So, in this paper, we survey the available methods for updating map information, especially that which is effectively unknown. Map updating systems can be generally classified into two fields: position and traffic sign detection, and network and cloud-based map generation and updating.

We review the position and traffic sign detection technologies in Section 2. Section 3 describes the technologies for network and cloud-based map DB generation and updating as they relate to the determination of unknown map information. Section 4 outlines some potential areas for future research, and we conclude this paper in Section 5.

2. Position Detection and Traffic Sign Detection Technologies

2.1. Position Detection Technologies

Position detection is the most fundamental and important calculation technology in navigation systems [1]. Navigation systems rely on the accuracy of position detection in order to calculate unit position and search path. Various position detection methods have been studied and implemented, including dead-reckoning, map-matching, and hybrid algorithms [4-8]. The hybrid algorithms most frequently applied to map matching are point-to-point matching, point-to-curve matching, and curve-to-curve matching [6-8].

Dead-Reckoning (DR) is a manner of self-contained navigation in which the current position of a vehicle is determined through calculations based on the traveling distance and direction of a vehicle as detected by its built-in sensors.

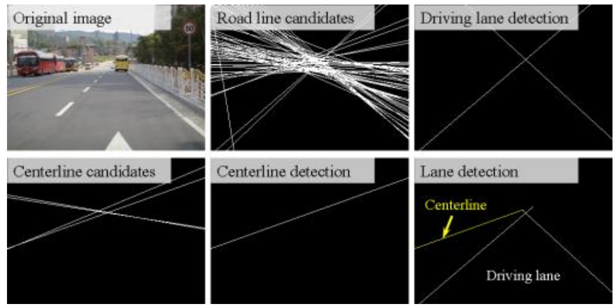
Over long distances or extended driving times, the assumed coordinates determined by the DR method will accumulate inaccuracies from sensor errors, and the position displayed on the map will not be reflective of the vehicles actual location. Map matching is a method of correcting for such sensor error by modifying the vehicles current map position relative to mapped features. That is, map matching corrects for cumulative error and marks the current position on a digital map by comparing the road shape from the digital map database with the traveling trajectory of the assumed coordinate detected by dead-reckoning.

The hybrid method uses speed sensors, direction sensors, and GPS to measure position. The shortcoming of the GPS method alone is that it cannot provide the current position absent a GPS signal, while dead reckoning alone suffers from cumulative error over time and distance. These individual shortcomings are overcome with the hybrid method.

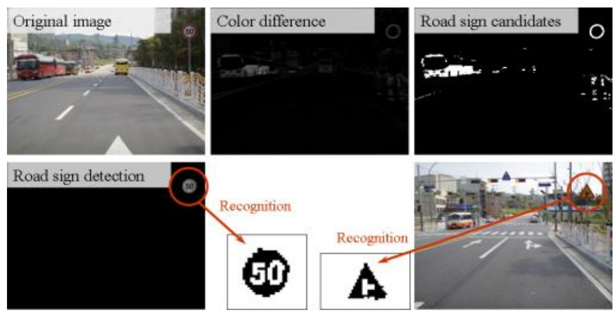
2.2. Traffic Sign Detection Technologies

Road lanes can be detected using line segments [9-11] as shown in Figure 1(A). The road lines including the centerline are detected by the Hough transform. The road line candidates of the driving lane are extracted from an edge image, while the centerline candidates are extracted from a yellow-color difference image. The road lines are selected from the candidates using the perspective and geometric information of the installed camera.

Various researches on the detection of road signs have been conducted [12-19] generally as shown in Figure 1(B). Road sign candidates are extracted from color difference images, and then candidate sign regions are detected using shape information. The attributes of road signs can be recognized by template matching because the figures and texts are standardized.



(A)



(B)

Figure 1. Road Lane and Sign Detection showing Extracted Road Attribute Values

Considering the researches, Fleyeh *et al.*, [17] proposed an eigen-based traffic sign recognition method that enables classification of unknown traffic signs based on a principal component analysis (PCA) algorithm that identifies the sign based on a comparison with the most effective components of known signs. A set of weights are computed from the most effective eigen vectors of the known traffic sign. Then, by using the Euclidean distance, the unknown traffic sign images can be classified.

Meuter *et al.*, [18] proposed a novel approach for a combined decision and object fusion algorithm for an automotive camera-based traffic sign recognition system. First, the algorithm separately determines the type of each object. Next, possibly matching signs are fused, and finally, a rule-based system selects the relevant signs.

Khan *et al.*, [19] proposed an automatic road sign recognition method based on image segmentation and joint transform correlation (JTC) with the integration of shape analysis. This method can detect the traffic signs of any country with any color and any of the existing typical road sign shapes (*e.g.*, circular, rectangular, triangular, pentagonal, and octagonal) and is invariant to transformation (*e.g.*, translation, rotation, scale, and occlusion).

3. Map DB Generation and Updating Technologies

3.1. Network based Map DB Generation and Updating Technologies

Various researches on methods for automatically updating the road map DB have been conducted.

Tao *et al.*, [20] proposed a reverse updating algorithm to update the road map DB using a large volume of raw GPS trace data. In this method, cars gather GPS information on unknown roads on additional, non-volatile memory. Then, a new road map is generated based on this raw GPS road information.

Sakamoto *et al.*, [21] proposed a data renewal method as a telematics service for a car navigation system. In this method, map data is read from a CD-ROM or DVD-ROM and then updated continuously from difference data downloaded through a cellular data connection. This method requires constant communication by cellular connection in order to deliver accurate road conditions.

The Locally Differential Map Update (LDMU) can be implemented by introducing the database management system (DBMS). The LDMU is a method of updating maps only partially so as to reduce the distribution data size. However, some problems occur when LDMU is applied to road data updates. For example, navigation functions such as the shortest path calculation make use of continuous network data, and the LDMU causes segments of the road network to be disconnected. Therefore, Asahara *et al.*, [22] proposed the Connection Maintained Locally Differential Map Update (CM-LDMU), which involves partially updating a map while maintaining road network continuity.

In the road Map Air Update Server (MAUS) project [23, 24], researchers have developed a mobile spatial DBMS to enable updates to portions of map data that could not be updated using the conventional navigation system [25-27].

SK M&C., Ltd. [28] demonstrated a service that can wirelessly update map data by using the SK-DigitalHub Service, through which map data and the driver's safety information are updated via a connection between the navigation system and a Bluetooth base station that can be installed at a gas station.

Toyota Motor Co., Ltd. [29] announced the Roadmap on Demand technology that it has developed to automatically deliver differential map data to car navigation systems. This service delivers updated maps through a network covering expressways and toll roads throughout the country, as well as ordinary roads near the driver's home and in the vicinity of a driver's intended destination. With G-BOOK mX, drivers can download updated map data at the touch of a button by connecting their cell phones to a compatible navigation system.

Honda Motor Co., Ltd. [30] demonstrated a method of wirelessly updating map information using mobile-phone networks, which is one of the services of the "Inter-Navi Premium Club," a communications service for automobiles. This method only updates the "differential data," or the difference between the original and latest map data.

The ActMap project of Europe [31] has been under development since 2004, and research regarding its interchange data format and server-terminal system has progressed. However, the project has failed to realize commercialization of the system.

Lee *et al.*, [1] proposed an automated, real time roadmap DB generation and updating architecture that uses GPS information and road image detection while driving unknown roads. When an unknown road that does not appear in the car's navigation map is driven, the network-oriented car navigation system can effectively extract the GPS information and image information of the unknown road. Subsequently, that extracted information is used to update the local roadmap DB in the car's navigation system. Updated roadmap information, for the unknown roads, is then uploaded to the roadmap DB provider to enhance the master roadmap DB.

3.2. Cloud based Map DB Generation and Updating Technologies

Cloud computing [32-34] can be described as on-demand, online utility computing system that operates on large-scale computer servers which store data and execute programs for the benefit of remote users. Cloud computing systems are accessed via the Internet, depending on user requirements, and can be defined as online tools that are semi-standardized and location independent. That is to say, the total environment, which consists of virtualized large computers, can provide remote access to devices including personal computers (PCs) or mobile devices. As cloud computing is deployed increasingly widely, most data resources can be stored and shared in a cloud computing DB center.

Lee *et al.*, [35, 36] proposed a cloud computing based roadmap generation method that could be used by and shared between heterogeneous car navigation system providers for the purpose of identifying and integrating unknown roads and features into a master map as in Figure 2(A). In the proposed method, when drivers travel unknown roads, the proposed method extracts the road attribute information and records it as metadata in an extensible markup language (XML) format. The metadata is proposed as a replacement for the proprietary roadmap formats presently used by the various roadmap providers, as it would enable efficient integration of road map information into heterogeneous navigation systems via a cloud computing environment. The providers of roadmap DBs can enjoy the benefit of real time map updates and, via the cloud environment, also provide users with complete roadmap information instantly and at any time.

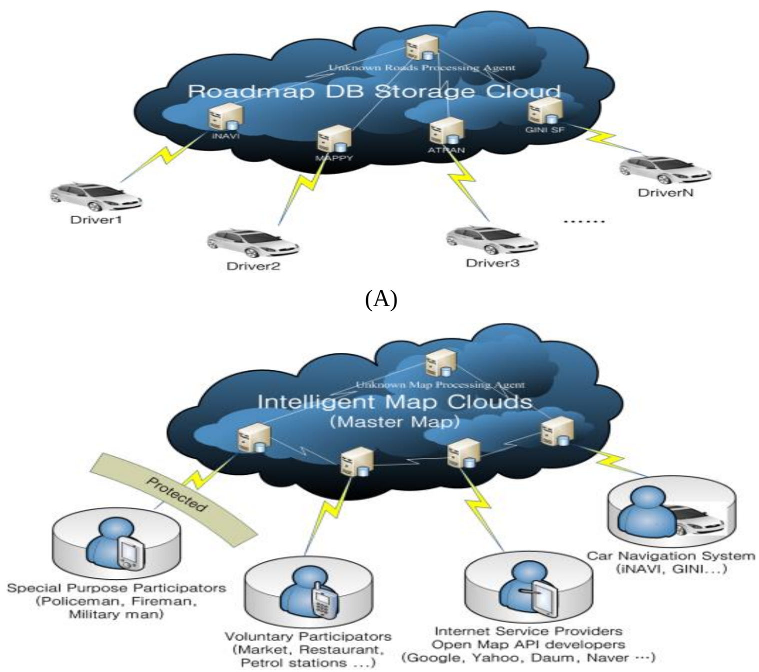
Lee *et al.*, [2, 3] proposed the concept for and architecture of the Open Map Generation environment based on Cloud Computing and a Mash-up Approach for the extraction of unknown map information and updating of the Master Map DB in the Intelligent Map Cloud as in Figure 2(B). This method can employ data from and serve data to Internet Service Providers (ISP) and voluntary participators using mash-up service up with open map APIs including the Google Maps API [37], Yahoo Maps API [38], Naver Maps API [39], Daum Maps API [40], Open Street Map (OSM) [41], Google Map Maker [42] and Paran Open Map [43], *etc*. These let voluntary participators easily embed rich and interactive maps into their web and desktop applications via myriad platforms.

4. Future Research Areas

Recently, many researchers have grown interested in mobile phone and car navigation system integration. Nokia has developed Terminal Mode technology [44, 45], which originated as an NRC research project, which proposes an industry standard for the integration of mobile phones and their applications into the car environment.

Terminal Mode is a standard that aims to enable the next generation of mobile devices and car integration systems by providing for the replication of a mobile device's screen on an in-dash display. It also allows interaction with the head unit and associated controls to be sent back to the mobile device. This enables the display of, and interaction with, services and applications running on the phone. This technology should be bidirectional so that the smartphone can access performance information from the vehicle itself and provide more relevant information to the driver. Thus, efforts should be taken to integrate vehicle position information with navigation services on the connected mobile device so that the driver can receive a more personalized and relevant service from his mobile device.

In addition, the metadata format for the exchange of cloud-based map information has not been standardized at present, thus more research on the topic is required.



(A)

(B)

Figure 2. Overview of Map Generation and Updating Environments based on Cloud Computing

5. Conclusions

We surveyed the various methods for updating unknown map information. In general, it does not matter how much map providers strengthen their inspection teams and increase the frequency of actual traveling tests; the quantity of road information that can be gathered in-house is likely to be surpassed by that from the drivers or voluntary participators who drive the roads every day. Whether or not a map of a particular roadway already exists, the information provided by actual drivers may significantly augment the quality of the map. Mutual integration and the sharing of map information through the cloud environment can improve the accuracy of map information in real-time, and at less cost than is currently required to achieve similar data quality. At present, when certain map information is unknown or there exists an area where map attribute information changes frequently, each map provider must conduct a duplicative and costly traveling test to maintain its master map DB.

Thus, the cloud computing and mash-up approach to updating map DBs can minimize the need for and cost associated with traveling tests presently conducted by each provider. More, the costs associated with maintaining the map DB data center can be shared between providers through the construction of integrated servers. Finally, map generation via the cloud computing approach can more efficiently maintain up-to-date map information in the end users' map DBs.

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Authors

SeungGwan Lee received a B.S., M.S. and Ph.D. degrees in the Department of Computer Engineering at Kyung Hee University in 1997, 1999 and 2004. He is an Associate Professor in the Humanitas College at Kyung Hee University since 2006.9. He was Visiting Professor in the School of Computer Science and Information Engineering at Catholic University in 2004 and 2006.8. His research interests include the artificial intelligence, meta-search algorithm, multiagents, ubiquitous computing, image processing and ITS.

Sungwon Lee received the Ph.D. degree from Kyung Hee University, Korea. He is a professor of the Computer Engineering Departments at Kyung Hee University, Korea. Dr. Lee was a senior engineer of Telecommunications and Networks Division at Samsung Electronics Inc. from 1999 to 2008. He is an editor of the Journal of Korean Institute of information Scientists and Engineers: Computing Practices and Letters.