LETTER Special Section on Artificial Reality and Telexistence

# A Reliable New 2-Stage Distributed Interactive TGS System Based on GIS Database and Augmented Reality

Seungjun KIM<sup>†a)</sup>, Student Member, Hojung KIM<sup>†</sup>, Seongeun EOM<sup>†b)</sup>, Nitaigour P. MAHALIK<sup>†</sup>, and Byungha AHN<sup>†c)</sup>, Nonmembers

Most of the traveller guidance services (TGS) are based SUMMARY on GPS technology and generally concerned with the position data mapping on the simplified 2D electronic map in order to provide macro level service facility such as drive direction notifications. Digital GIS based GPS entails in situ intuitive visualization. The visually enhanced TGS can improve the global and local awareness of unknown areas. In this paper, we propose a reliable new TGS system that provides 3D street as well as pinpointed destination information in two stages of its interactive services; web-based and AR-based. The web server generates a guiding path on 2D digital map and displays 3D car-driving animation along the path. And, the AR-based service is embedded so that users can interactively obtain the detailed micro-level information of a specific section in the area with their fingertips. The implementation is based on autoformation of on-line GIS data structures from the available priori. For the verification, a 5×4 road network is selected as a test area. In the service demonstration, we show the effective awareness of street environments and the usefulness of this new TGS system.

**key words:** traveller guidance service, GIS, ITS, fingertip interaction, augmented reality

## 1. Introduction

With the high growth of GPS (Global Positioning System) technology research and development on digital, GIS (Geographical Information System) has drawn significant attention in transportation, topographical, military and academic fields in order to foster powerful spatial analytical capabilities. The effective visualization of geospatial information tends to center around the offer of intuitive visual-information whose range and details are determined according to the types of GIS database services. The creation of new geospatial database that is appropriate to the services (macro- or micro-level) becomes an indispensable process for the reliable and effective realization of digital GIS [1]–[4].

At the same time, visualization of geospatial data is one of the most active application areas for augmented reality (AR) and computer graphics technology. The noteworthy researches on the geospatial application of AR were performed in Tinmith project [5] and AR PRISM interface [6]. Tinmith project has focused on the mobile outdoor

Manuscript received March 11, 2005. Manuscript revised June 19, 2005.

<sup>†</sup>The authors are with the Department of Mechatronics, Gwangju Institute of Science and Technology (GIST), 1 Oryoungdong, Buk-gu, Gwangju, Korea.

a) E-mail: zizone@gist.ac.kr b) E-mail: seueom@gist.ac.kr c) E-mail: bayhay@gist.ac.kr DOI: 10.1093/ietisy/e89–d.1.98 AR interfacing for interactive TGS
 We performed several case studies by using the designed platform. The system works well with maximum satisfaction. This paper demonstrates only one experiment.

AR system that integrates subsystem modules and wearable computing, head-mounted display, compass and interaction tools. It can be applied for city models creation, metro 3D building construction, and wire frame campus building design. In Nicholas R. Hedley and his colleagues' work [6]–[8], explorations in the use of hybrid user interfaces for collaborative geographic data visualization were shown with a summary of GIS- and VR-related demonstration. Also, due to the convenience of network service and user-friendly control, integration of 3D technologies has taken momentum to improve the visualization capability in GIS [9], [10]. Further, we emphasize that the design of user-friendly interface is becoming a kind of de facto principle in realizing effective

Most of recent urban areas are systematically constructed with city planning so that the information on *metropolitan road* network and its traffic facilities becomes very important geospatial information to travellers. In this paper, we present a TGS (Traveller Guidance Service) system with two different service types, web-based and AR-based, taking into account of real-world constraints of the target regions in a metropolitan district. Firstly, we have implemented a web-based system with newly proposed GIS data structures of an urban area, and then shown how it can be converted to the AR interaction service for a specific section in the area. In particular, the following attempts have been made, in order to design a full-fledged reliable two-stage TGS system.

- Requirement analysis for new 3D TGS
- Prototype platform design of 2-stage 3D TGS system
- Novel GIS-based geospatial data structure
- Detailed 3D representation of the test district

## 2. Requirement Analysis

GIS system [11].

## 2.1 Apprizing TGS Systems

The services of GIS-based TGS systems can be divided into three layers; Web-based district information service, Webbased traffic information service and CNS (Car Navigation Systems) service.

The first web-based district information services offer literal- or pictorial-type information about the major facilities such as hospitals, theaters or restaurants in a district with briefly-sketched guidance map. 'Keyword search' is widely used as an inquiry method for the information. The service is focused on the geospatial position guidance so that route guidance to the target place is well presented while the information on neighborhood road conditions is less considered. It was importantly reported, however, that travellers in their first visit to a target place rely preferentially on traffic-control or road sign (44.3%) and road map (24.8%) according to the latest surveys concerned with the road sign system [12], [13]. Slight difference of the actual road environment from the traveller's estimation can not cause only mistaking the route but also incident under driving [3], [14], [15]. In addition, 3D figuration of the facility outlines has been recently provided to enhance user's visual intuitiveness in the manner of positioning box-like graphic primitives on the sloping 2D map. Although 3D maps using 3D viewpoint control have been experimentally introduced, however, it has difficulty in the construction of supportable geospatial database in actuality as well as is still at an early stage [19].

Next, traffic information services offer highly-reliable information about traffic conditions, public transportation guide, weather, or construction region by utilizing RF-beacon & probe vehicles, traffic correspondents or CCTV. However, the users are very few due to the high cost as well as tend to rely on their empirical knowledge because traffic congestion in the National Capital region becomes almost chronic so that only traffic information itself is not helpful [14]. In the case of most public transportation guide, database is well constructed; however, vehicles' intervals are usually unkept and the locations of their stops are hard to find in actual environment except subway.

The last CNS services provide users' position information usually on GPS terminals such as PDA in GIS-map style representation. Optimal or shortest route information is complementally offered. Differently from the web-based services, a GPS receiver, a terminal and a digital map are necessary. While the road images are simplified in 2D vertex and line form at the early stage, the information about the road and its surrounding environment to be represented in 3D has been attempted, noticeably in Japan.

## 2.2 Key Requirements

For the configuration of our service items and the reliability validation afterward, we specified users' requirements for TGS by e-mail questionnaire method before our implementation. In the way of priority marking, three categories were asked to fifteen applicants who were computer literate: (1) preference to the existing road-traffic information in real-live driving situation, (2) defects of the existing 2D web-based TGS, and (3) demands for useful 3D TGS. The following major results of each category are firstly considered for our TGS system implementation.

- The most helpful information in real-live driving situation is the directional board and crossroad information.
- The first defect is the absence of directional board and neighborhood building information.
- Realistic and detailed representation of the road appearance will be more helpful than of traffic facility (To the level of road width and the number of car lanes).

## 3. System Overview

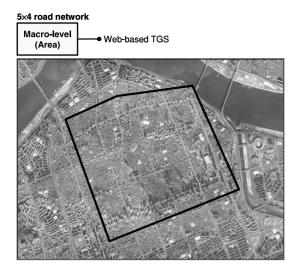
## 3.1 Modular Representation of Target Area

The representation of target area is modular in nature. Firstly, we selected a test area and a section; a subset of the test area. The 'area' means a region composed of metropolitan road network such as streets and avenues. Bearing in mind that a matrix of paths where the public transport is available and travellers can mainly pass through only by vehicles, the 'section' in the area implies a smaller region like a kind of prepared land for building lots such as a town, a complex or a zone of interest (e.g. a company town, a research institute, a university campus, a general hospital zone, a shopping town with many malls, a tourist zone, a stadium complex, an apartment complex, etc). Hence, the section is very likely to be a destination place to the travellers. We define the macro- and micro-service in 2-stage TGS system as web-based TGS for the area and AR-based TGS for the section, respectively. As shown in Fig. 1, we have selected a 5×4 road network of Gangnam in Seoul, Korea, as a test area and our institute GIST (Gwangju Institute of Science and Technology) as a section, and then we make the section be positioned at a destination-candidate place in the area for service demonstration.

## 3.2 Prototype 2-Stage 3D TGS System

Based on the reliable GIS sources, we newly design a module in order to incorporate novel geospatial data structures, SMFs (GIS metafile format co-produced by SI lab of GIST and Symtech System, Inc. [16]), for links, nodes and traffic facilities in the test area. The physical and logical configuration is presented in Sect. 4.1. The data sessions of each structure are constructed using a custom-built data-editing program module (DEPM). With the help of the module, the 3D geospatial database can be constructed by adding some supplementary data like texture images, building geometries and informative texts. The architectural design view of the module for database generation is shown in Fig. 2.

As shown in the figure, our system offers two different types of services, Web-based and AR-based, which depend on the district scope, area and section. In the web-based service, there are two subsystems, a video retriever and a path generator, which works while a client user connects to the traveller guidance site via Internet. If s/he selects a departure and a destination place in the test area, the path generator determines the shortest path between them and



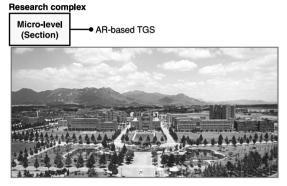


Fig. 1 Test area and section.

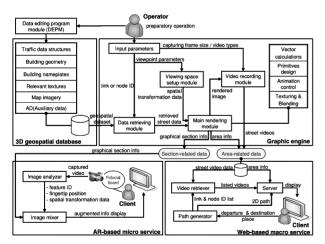


Fig. 2 System architecture of the prototype TGS system.

makes an animation sequence list of the path. Then, the video retriever mounts the link and node videos recorded in the graphic engine sequentially on the server according to the list. And the video retriever is independently interfaced on the applied shortest path algorithms of the path generator. In this service, the user can confidently obtain the 3D street information and the 2D guide path of the area.

The AR-based service is related to the destination sec-

tion of interest in the area. A generic monitor-based AR system with ARToolKit [17] is designed and interfaced. This fundamental AR environment setting is employed for the fast prototyping while expecting future extension of its platform combined with widely-used see-through HMD (Head-Mounted Display) or other displays in spatial AR applications [22]. The user needs a web-camera and a rectangular board as a tracking feature. The feature tracker analyzes the captured scene from the camera and tracks the feature rectangle. The tracker can calculate the spatial relationship between the board and the cam in 4×4 transformation matrix form, which is performed through the processes; image thresholding → connected region detection → contours detection  $\rightarrow$  line extraction and corner detection. Finally, the image mixer overlays the virtual imagery of the graphic engine on the live video scene. In this service, the fingertip interaction function has been implemented, which is described in Sect. 4.3.

Besides DEPM, the other module of primary interest is the graphic engine that facilitates animation control. The graphic engine is developed taking into account of data structures and each service type. The engine retrieves numerical data from the database and performs geometric calculations and 3D rendering techniques. The animation control module, which configures the viewpoint navigation and records the rendered scenes in the selected video formats, has been embedded into the engine. It provides fully 3D street models for the area and mixed models of 3D buildings and 2D map texture for the section. The 3D graphical modelling of the street components is described in Sect. 4.2.

# 4. Modelling and Implementation

## 4.1 Geospatial Data Structure Design

To design a new GIS format for the test area, field investigation for texture images based on the electronic topographical maps on scales of 1:1000 and 1:5000 of Korea National Geographic Information Institute was conducted in first place. Our geospatial database is built in layered structure applying persistent topology approach [18] for the enforcement of data consistency and more efficient storage of geospatial data.

As shown in Fig. 3, the test area is composed of 102 links (L) and 43 nodes; 20 general nodes (N), 17 entry nodes (EN) and 6 dummy nodes (DN). The 'link' represents a half side of a straight roadway and the 'node' is a crossroad between diverged links. The node IDs are assigned with four digits. Link IDs are automatically determined with eight digits derived from up-node ID and down-node ID. Later, we have used these IDs for handling animations. As shown in Fig. 4, link ( $id_0$ , $id_1$ ) represents the connected driveway from node ( $id_0$ ) to node ( $id_1$ ). The neighboring nodes are connected with two contrary directional links. The 'dummy node' is defined for the creation of curved links as shown in the figure and the 'entry node' is the outer border of the area.

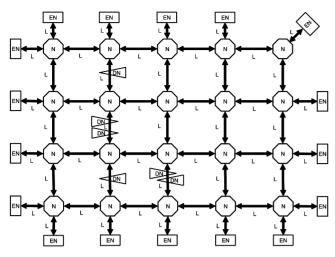


Fig. 3 Entire links and nodes in the test area.

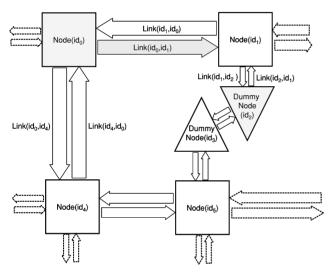


Fig. 4 Link and node ID assignment.

Basically, the link data structure composed of 19 driveway data (e.g. road width, median strip, stop-line location, car lanes, etc). We categorize the DB format into eight data structures; one for the links, another for the nodes, and the others for traffic facilities. In addition, the data sessions for U-turn pocket, footway, bus bay, and arrow marks are consecutively constructed. Next, in the node, the data sessions are filled with the information about traffic island, safety zones, footway, arrow marks, etc. Entry node has only a node ID and an indicator, and the dummy node contains five vertexes, median strip and lane data. Lastly, the data structures for the traffic facilities are constructed in their own format. Each facility has a link identifier that it belongs to and a type indicator; buildings (01), signal lights (02), directional boards (03), bus stops (04), and crosswalks (05). We described the specific data sessions of each structure in [1].

## 4.2 Graphical Implementation

Road condition, traffic facilities, signal systems and lined-up buildings are vital information to travellers. For instant, in a section, exact building location and appearance are useful. Both in the data structure composition and in the graphic rendering, geometrical consistence has been a main concern to us. The link connections to nodes as well as counterpart links have to be rightly accorded. This entails implementation of graphic engine in order to perform the rendering methods and a number of vector calculations in accordance with new GIS formats and service requirements.

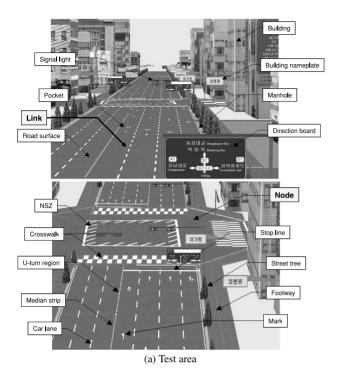
For example, the buildings are to be differently modelled according to the service modes. In this validation study, for the web service, only the lined-up buildings along the links have been considered, taking into account of building sizes and textures. We have also put nameplates of the buildings to improve reliability. While the buildings in the AR service are drawn in detail based on their blueprints, the location and pose of them are reflected closely to real. Additionally, virtual icons are positioned on an augmented map at the building locations to interact with fingertip. We designed 3D GIST buildings based on the numerical values in the blueprints; five department buildings, an administrative center, a library, a student union, an entrance gate, and several buildings for the research and manufacturing, etc. The 3D graphics of the test area and the section are shown in Fig. 5. Rendering of 3D streets has been performed using OpenGL.

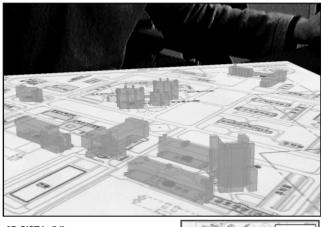
The direction boards, bus stops, signal lights and cross-walks have been positioned according to the location data in the structures, while other extra features such as road-side trees, street lamps, and manholes have been taken as fixed size and distance. For the street lamps and roadside trees, blending techniques to their texture mappings are applied in order to prevent occlusion with background scene. In addition, we have considered the directions of branches of lamps and directional boards to be extended toward the center of links. Vector calculations including inner/cross products, derivation of normal vectors, and intersection points between two vectors are performed.

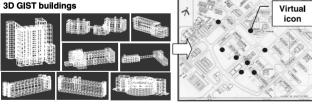
To offer realistic navigation to the traveller, driving animations is implemented. The driving paths in nodes are generated using Bezier curve equation. It suggests the camera-arrival position in a link has to meet to the departure position of the next node, and vice versa. In the graphic engine, we set window frame size, camera position, translation speed and video types parameters for the car-driving animation and recording. The recorded videos are mounted on the web-server.

## 4.3 AR Interface with Fingertip

The AR service provides 2D & 3D information of the section and the user interaction with bare hand, which is one of the most initiative approaches for natural gesturing in AR



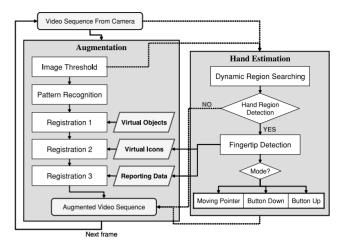




(b) Test section

Fig. 5 3D graphic outlines.

applications [19], [20]. Open-source library, ARToolkit, is used to calculate camera pose relative to known patterns at 30 frames per second utilizing IBM compatible desktop PC, fast enough to augment video. The AR module can be integrated into the existing workplace using available state-of-the-art interface technologies. Besides, different AR contents (CG contents including interaction mode) of a section can be individually offered at a time by employing several patterned-markers.



**Fig. 6** AR interaction procedures with fingertip.

For the stable augmentation, we have employed a multi-type pattern formed by four markers as a tracking feature. Although hands or fingers occlude some of markers, augmentation is ensured by detecting other visible markers. And, a noise filter is applied to resolve the trembling problem of augmented virtual models in the user's static view state. Four corner vertices of marker are tracked while showing slight but flickering variation, which affects the element values of transformation matrix from marker to camera coordinates. It is almost unaware in the user's dynamic view state; however, it can disturb users' observation in their static view. So, in our system, those elements are enforced to take the average of previous values when the variations are within given constraint. If the variation is larger than the constraint, the motion of marker is regarded as in the dynamic state and the filtering pauses.

Using this integrated system, users can control virtual icons with their fingertip navigating over the map, which acts like a mouse pointer. Fingertip detection is conducted while a hand encroaches on the patterned area. If fingertip stays on the virtual icon areas for a second, it is recognized as a mouse clicking and the predetermined functions are executed. To reduce searching area, dynamic region searching [21] is applied. And fixed threshold value is used to detect the hand feature. The fingertip position determined by the minimum value of the hand feature in screen coordinates has been compared with the screen-projected coordinates of the virtual icons in 3D world space. In Fig. 6, the task procedures between the hand estimation and augmentation process is shown.

This AR-based TGS is interfaced to web-based TGS system by three Boolean-type control parameters; microservice request, node ID request and arrival flag. When a web-based TGS operation is completed, node ID of the destination is referred to the AR interface. Arrival flag is also transferred at this time. As shown in Fig. 7, AR contents of the destination node is processed since arrival flag parameter and node ID data are transferred.

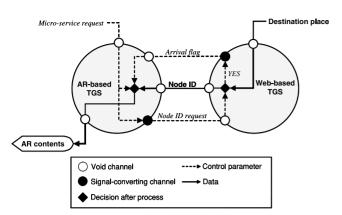


Fig. 7 Operation of AR interface by web-based TGS interface.

### 5. Service Demonstration

Figures 8 and 9 show an experimental demonstration with regard to the services that the designed guidance system provides. In order to use, first of all the user has to establish a connection to the web-based traveller guidance site. At this point, choices of departure and destination place like subway stations, well-known hospitals, famous companies, etc are made. The site then displays the shortest path on 2D guidance map, which in turn provides information on crossroads and/or turns. The passing time and distance is automatically predicted. In the demo, a subway station and GIST are selected as the departure place and as the destination place, respectively.

The street information with 3D car-driving animation interfaces five items; a main 3D view, a 2D path map, a front directional board, turning direction indicators, and animation control keys. While passing along the 3D streets, the site informs us the next turning direction, the present position on the 2D path map, and a directional board that the traveller would meet at the front crossroad. Moreover, the street condition of unknown area such as the road widths, lined-up buildings with their nameplates, the availability of U-turns and the existence of bus bays or pockets can be known in advance.

The last animated node prompts the traveller to avail the AR service for the desired section. Since, the traveller has arrived in a destination section, the search for the specific building should start. The detail 2D map of the section is augmented on a multi-type pattern. The map imagery over-laid on the board can be switched according to the sections.

There are virtual icons located at the exact building positions on the map. To get the detailed building information, the user clicks on one of them with fingertip or mouse. Then, the appropriate 3D building model is overlaid on the map. Its appearance and pose are reflected on it, as well as the text information like building name is annotated. The user can move and rotate the patterned board as if the destination section is miniaturized on it. Additionally, there are two extra

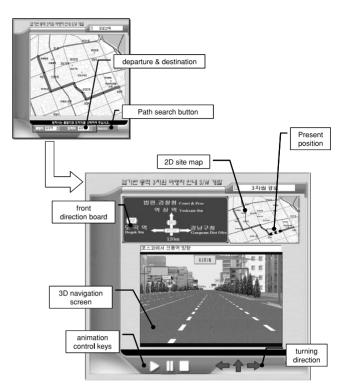


Fig. 8 Web-based service for area.

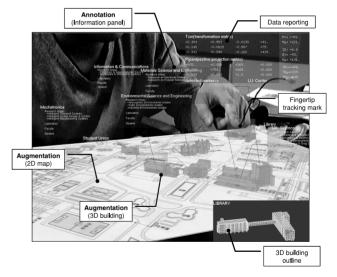


Fig. 9 AR-based service for section.

views on the screen; right-top view which reports the present fingertip position and the detected marker ID, right-bottom view which shows the outlines of the building in animation. These are independently displayed on the board motion (See Fig. 9). The interaction steps are explained in Fig. 10.

For the validation of the proposed implementation, the prior applicants have been asked to visit our demonstration site. And reliability and usability are tested in questionnaire method by scoring. Specific procedures and interim results were reported in [1], [16]. In the reliability test, none of service items was evaluated as dissatisfaction. It seems because

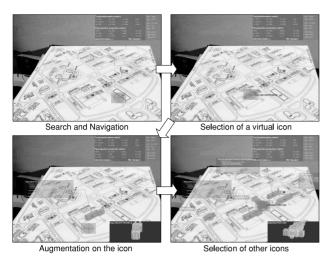


Fig. 10 Interaction steps in AR-based TGS (captured in mouse-interaction mode).

Table 1 Usability summary.

Index	Service items
Very useful	2D path guidance/ Front board notification
Useful	3D driving simulation/ Detailed road outlines/ Building nameplate/ Front turning direction/ Present movement direction
Useless	Nothing
Opinions (future demands)	- Flexible viewpoint movement in 3D screen - Public transportation information - Point-navigating display of the present position on 2D map

the implementation of our system has been initiated on the basis of the reliability requirement specification.

The usability of our TGS system is evaluated as in Table 1. We have noted two interesting results. One is that the applicants demanded higher viewpoint than driver's real view in 3D screen. And the path guidance on 2D map was evaluated higher than 3D driving simulation for the path contrary to their prior requirement. At the same time, most of the applicants have gazed devotedly the varying present link notification on the map in accordance with the 3D simulation above other existing TGSs of Sect. 2.1. It means that the 3D service items as TGS complements manifest the enhancement of users' immersion in the service enough as expected. Nevertheless, the service items for the global awareness of the target area are prior to the realistic representation.

## 6. Conclusion

In this paper, we have presented a reliable interactive traveller guidance service (TGS) system with what we call macro and micro service facilities through web- and AR-based implementations, respectively. Compared with the existing TGS systems, the designed platform provides more realistic street condition in 3D domain. From web-based

service, the traveller can easily obtain the visually enhanced street information on the guiding path and from the AR-based service, the pin-pointed destination (micro service) in a specific *section* of an *area* is confidently acquired through intuitive interaction with fingertip. In the validation of the proposed implementation, we have demonstrated that the 2-stage platform performs well providing satisfactory usability as 3D TGS. The reliability was tested based our several experiments and questionnaire method. The flat plane satellite imagery-like animated view needs to be amended to reflect the altitude of the ground for more realistic geography visualization. Further, practical AR platform and interaction may be accounted for future considerations.

## Acknowledgements

This work was supported by the Ministry of Construction and Transportation (MOCT) and carried out as a joint research of GIST and SimTech Systems INC in Korea. The authors gratefully acknowledge the contribution of Dr. Eunseok Choi in SAIT (Samsung Advanced Institute of Technology) and Myunghwan Bae in SimTech Systems.

#### References

- [1] S.J. Kim, S.E. Eom, S.C. Byun, S.M. Yang, and B.H. Ahn, "Traveler guidance system based on 3D street modeling," Proc. 2004 Int'l Conf. on Control, Automation and Systems (ICCAS 2004), pp.1187–1190, Bangkok, Thailand, Aug. 2004.
- [2] H.J. Kim, J.S. Han, T.H. Shin, and B.H. Ahn, "Development of 3D interface program for the micro traffic simulation —Focused on NETSIM—," Proc. Korean Society of Transportation fall Annual Conference, pp.23–27, 2000.
- [3] H.J. Kim, S.A.A. Shah, H.H. Jang, and B.H. Ahn, "Microscopic simulation in decision support system for the incident induced traffic management," Proc. 9th Int'l Conf. on Knowledge-based Intelligent Information & Engineering Systems (LNCS/LNAI 368), pp.255– 260, 2005.
- [4] Y.S. Cho, H.J. Kim, and S.K. Lee, "Development of microscopic tollgate simulation using SIMPLUS," KSCE J. Civil Eng., vol.22, no.6-D, pp.1045–1055, 2002.
- [5] Tinmith Project, http://www.tinmith.net/
- [6] N.R. Hedley, M. Billinghurst, L. Postner, R. May, and H. Kato, "Explorations in the use of augmented reality for geographic visualization," Presence: Teleoperators and Virtual Environments, vol.11, no.2, pp.119–133, April 2002.
- [7] N.R. Hedley, C.H. Drew, E.A. Arfin, and A. Lee, "Hagerstrand revisited: Interactive space-time visualizations of complex spatial data," Informatica, vol.23, no.2, pp.155–168, 1999.
- [8] T.A. Slocum, C. Blok, B. Jiang, A. Koussoulakou, D.R. Montello, S. Fuhrmann, and N.R. Hedley, "Cognitive and usability issues in geovisualization," Cartography and Geographic Information Science, vol.28, no.1, pp.61–75, 2001.
- [9] M. Reddy, Y. Leclerc, L. Iverson, and N. Bletter, "TerraVisionII: Visualizing massive terrain databases in VRML," IEEE Comput. Graph. Appl., vol.19, no.2, pp.30–38, 1999.
- [10] C. Zhu, E.C. Tan, and T.K. Chan, "3D terrain visualization for web GIS," Proc. Map Asia 2003, AD65, 2003.
- [11] N.P. Mahalik, J.H. Ryu, and B.H. Ahn, "Simulation integrated management for embedded DCN," Comput. Stand. Interfaces, 2005 (in press).
- [12] Final Report, "Road sign design system development project," Seoul Development Institute, Korea, 1998.

- [13] Y.G. Lee, S.K. Park, and H.M. Kim, "Improvement of traffic information system for traffic safety —Focused on VMS—," Research Report, Traffic Safety Authority, 2004.
- [14] S.A.A. Shah, H.J. Kim, S.K. Baek, H.H. Chang, and B.H. Ahn, "Incident impacts forecasting for non-recurrent freeway traffic congestion management," Proc. 3rd Int'l Conf. on Computers, Communications and Control Technologies: CCCT'05, pp.134–139, 2005.
- [15] S.A.A. Shah, H.J. Kim, and B.H. Ahn, "Post-incident decision support system for freeway incident analysis and traffic management," Int'l ITS Conference, pp.67–74, 2005.
- [16] SimTech and GIST, Final Research Report, Web-based 3D Traveler Guidance System, 2001.
- [17] ARToolKit, http://www.hitl.washington.edu/artoolkit.
- [18] D. Galdi, "Spatial data storage and topology in the redesigned

- MAF/TIGER system," U.S. Census Bureau Geography Division, 2005.
- [19] G.G. Yun, S.J. Kim, S.E. Eom, and B.H. Ahn, "3D augmented reality map with fingertip interaction," Proc. 2004 Korea Human Computer Interaction (HCI 2004), pp.598–604, Pyongchang, Korea, 2004.
- [20] C. McDonald, Hand interaction in augmented reality, Master Thesis, Carleton University, Jan. 2003.
- [21] S.E. Eom, I.L. Lee, G.G. Yun, and B.H. Ahn, "Hybrid image segmentation using edge and region growing," Proc. IEEK Conf. IV, vol.26, no.1, pp.2299–2302, 2003.
- [22] O. Bimber and R. Raskar, "Modern approaches to augmented reality," Proc. EUROGRAPHICS 2004 Tutorial 8, Grenoble, France, Aug./Sept. 2004.