Traveler Guidance System based on 3D Street Modeling

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Abstract: This paper presents a traveler guidance system that offers 3D street information such as road types, signal light systems, street trees, buildings, etc. We consider 5x4 road system of Gangnam(in Seoul, Korea) as a test area and reflect the traveler's car-driving situation. A web server is constructed to serve traveler's driving path by switching 3D animation scenes automatically. To do batch processing of geometric data for the 3D graphical streets construction, we have extracted major street information from present GIS database and created new GIS file formats (SMF files), which contain data sessions for links, nodes, and facilities. With these files, we can render 3D navigation scenes. A number of vector calculations were performed for the geometrical consistence and texture-mapping method was used for the realistic scene generation. Finally, we have verified the effectiveness of the service by operating a test scenario. We have checked whether traveler's 2D path and 3D navigation are exactly reported after setting specific departure and destination. This system offers us well awareness of streets and takes useful role of traveler guidance.

Keywords: Traveler Guide Service, ITS, 3D simulation, Street Information

1. INTRODUCTION

Nowadays, concerns about the construction of useful digital GIS database are highly increasing for the effective management and visualization of the massive geographic information. With high growth of GPS technologies, many commercial products are developed to offer exact position information to traveler. Moreover, the web becomes a new user-friendly interface which can offer geographic information in rich display forms using web 3D technology [1,2]. As described in [3], many researchers tried to integrate of visualization techniques and GIS [4,5], and also make an urban model with an automatic data capture by the integration of different types of information [6]. In ETRI (Electronics and Telecommunications research Institute) of Korea, various researches of 3D virtual GIS applications based on Internet have been carried out in [7~11].

We can summarize the research trends of GIS applications in two aspects. The one is web-based system design with user-friendly interface and the other is a successful 3D visualization of geographical information. In this paper, we have considered how travelers guide service can be effectively implemented with present GIS database and proposed a new web-based system, which realistically offers road traffic information including facilities. In chapter 2, we introduce our system architecture with the explanation of major tasks in each system module. 3D streets implementation steps are described in chapter 3, and then we show our demonstration service uploaded on a web site in chapter 4.

2. SYSTEM OVERVIEW

We have selected 5x4 road system of Gangnam(in Seoul, Korea) as a test area and reflected traveler's car-driving situation. Fig.1 shows overall system architecture composed of two main databases; a Driving Path DB and a 3D Animation DB. If a user connects to the web-based traveler guide site, he can select departure and destination place at first. Then, the Driving Path DB determines the shortest path of them and lists all street videos of the route, and also car-driving animations in the 3D Animation DB are sequentially called and played according to the list. The user can refer street information of the route in forms of 2D site map and 3D street model.

To develop this service system, we have constructed new data structures based on present GIS database and developed a graphic engine for 3D street modeling. After the engine render 3D scenes, their 3D animation files are created as outputs and listed according to Link and Node; Link represents a half side of a straightly spread roadway, and Node represents a crossroad including simple connecting parts of links. The web-server, in which the listed video files are stored, plays a role of user interface while displaying three reporting screens. We have explained detailed task modules in chapter 3.

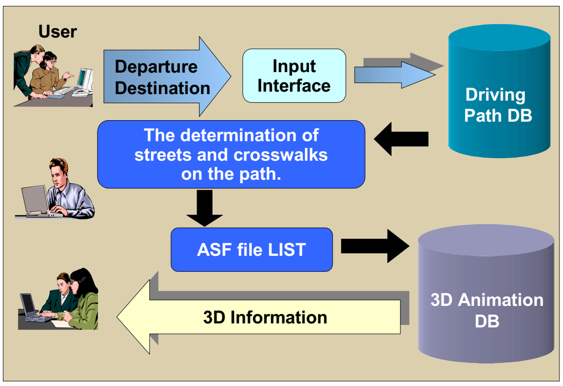

Fig. 1 System architecture

3. 3D STREET MODELING

3.1 Data extraction

As the first step, we extracted street information from present GIS database to create new GIS file formats (SMF files), which contain data sessions about links, nodes, and facilities of a test area. To collect geographic data at a minimum, we've sorted out indispensable data. We used a 1:1000 electronic map of National Geographic Information

Institute in Korea, but some field investigation is needed to get the detailed information of roadside trees, directional board, and footway, etc. As shown in Fig 2, we construct a 3D traffic map database for 3D graphical construction of streets to do batch processing of geometric data.

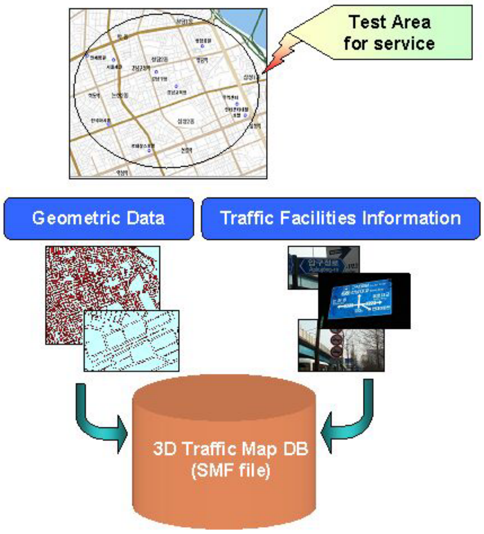

Fig. 2 SMF 3D Traffic DB

3.2 Data structure

In this section, we show data structures of links, nodes, and facilities. As shown in Tables 1~2, we unified links and node information to do batch processing by one graphic engine. Each data structure composes of only numerical or character data. In link data structure, there is driveway information such as road width, median strip, U-turn pocket, bus bay, footway, and arrow marks on the road, etc, while node data structure contains traffic islands, safety zones and outline coordinates, etc.

Table 1 Link data structure

Basic 19 data

Link ID	Link Name	Node ID		4-coordinates	Median strip		Pocket		Stop-line Location (Distance)	The number of lanes except in pocket	Total of lanes
		Up	Down	$(x_1,y_1)\cdots(x_4,y_4)$	Type	Width	Length	The number of lanes			

U-turn lanes(No more than 1 in the sample site)

U-turn lane index (Link ID_1)	Location	Length	End of Data
	If no U-turn lane → no data		9999

Footway(Sidewalk)

Footway index (Link ID_2)	Width	Start Width	Total of gaps	1st Distance	1st Gap	…	Last Distance	Last Gap	Last coordinate(x,y)	End of Data
	If no Footway → no data									9999

Bus bay

Bus bay index (Link ID_3)	Width	1st Distance	1st Length	…	Last location	Last length	End of Data
	If no Footway → no data						9999

Arrows on each lane

Each lane index	The number of arrows on this lane	1st arrow		2nd arrow		…	Last arrow		End of Data
		Type	Location	Type	Location	…	Type	Location	
Link ID_41	k_1	k_1 arrows				…			9999
⋮	⋮	⋮		⋮	⋮	⋮	k_n arrows	⋮	⋮
Link ID_4n	k_n								9999

n lanes

Table 2 Node data structure

Basic data

Node ID	Node Name	Total of coordinates data(n)	n-basic coordinates	End of Data
			$(x_1,y_1)\cdots(x_n,y_n)$	9999

Footway(Sidewalk)

Footway index (Node ID_Fnode)	Total of footway (generally, 2/n)	2n-coordinates	End of Data
		$(x_1,y_1)\cdots(x_{2n},y_{2n})$	9999

NTI(Traffic Island) – NSZ(Safety zone) – Nmark(Arrows on node road)

Each index	Each total	Type	Coordinates(3-4-2)	End of Data 9999	
Node ID_NTI_0	k_1		$(x_{01},y_{01}),(x_{02},y_{02}),(x_{03},y_{03})$		k_1 NTI
⋮	–	⋮	⋮	⋮	
Node ID_NSZ_0	k_2		$(x'_{01},y'_{01}),(x'_{02},y'_{02}),(x'_{03},y'_{03}),(x'_{04},y'_{04})$		k_2 NSZ
⋮	–	⋮	⋮	⋮	
Node ID_Nmark_0	k_3		$(x''_{01},y''_{01}),(x''_{02},y''_{02})$		k_3 Nmark
⋮	–	⋮	⋮	⋮	

Nch: Driving guide-line

index (Node ID_Nch)	Total of Nch (usually 0)	End of Data
		9999

And, the data of facilities around or on links & nodes was also stored in their own data structures, as shown in Table 3. With a belonged Link ID, each facility has an indicator; buildings (01), crosswalks (05), directional boards (03), signal light (02), bus stops (04).

Table 3 Facility data structures

Building

Indicator (1)	Belonged Link ID	Area Name	Name	Total of outer fence (n, usually n=4)	n-coordinates	n-heights	n-texture names	End of data
					$(x_1,y_1)\cdots(x_n,y_n)$	h_1~h_n	Tex_1~Tex_n	9999

Crosswalk

Indicator (05)	Belonged Link ID	Type	4-coordinates	End of data
			$(x_1,y_1)\cdots(x_4,y_4)$	9999

Streetlamp

Indicator (07)	Belonged Link ID	Root location	Type	End of data
		(x,y)		9999

Direction board

Indicator (03)	Belonged Link ID	Root location	Type	Height	Branch length	Total of texture(n)
		(x,y)				

Signal Light & Bus stop

Indicator (02 & 04)	Belonged Link ID	Type	Root location	Height	Branch length (if bus stop → 0)	Total of texture(n)
			(x,y)			

Each face

Numbering	Face indicator	Left-up coordinates (local coordinates)	Board width	Board height	Texture name	End of data
1	front=1 or back=2	(x_1,y_1)	w_1	h_1	Tex_1	
⋮		⋮	⋮	⋮	⋮	
n		(x_n,y_n)	w_n	h_n	Tex_n	9999

3.3 Graphical implementation

We have graphically implemented 3D streets using OpenGL. We made a vector calculation library to derive a large amount of 3D vertexes & vectors with given vertex data. Figs.3~6 show which part of a street each data section represents and what kinds of textures are used for realism. Most of all, the connecting part of neighborhood links and nodes has to be well considered.

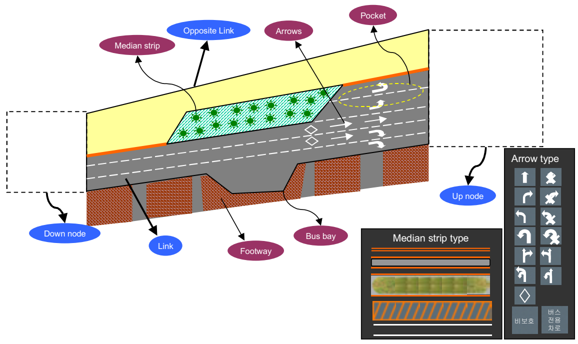

Fig. 3 Link modeling

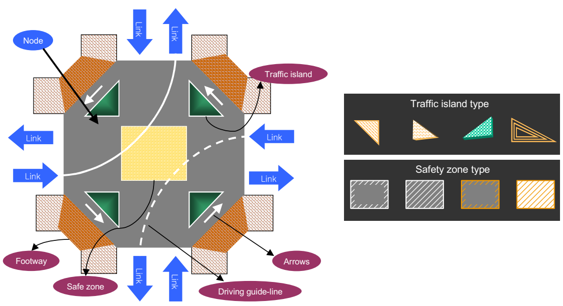

Fig. 4 Node modeling

For the placement of street lamps and roadside trees in Fig. 5 and 6, we've applied blending techniques to their textures, which are transparently mapped to prevent the occlusion with background scene. Moreover, the branch directions of lamps or directional boards have to be rightly positioned to the center of links using normal vector derivation and inner/cross products.

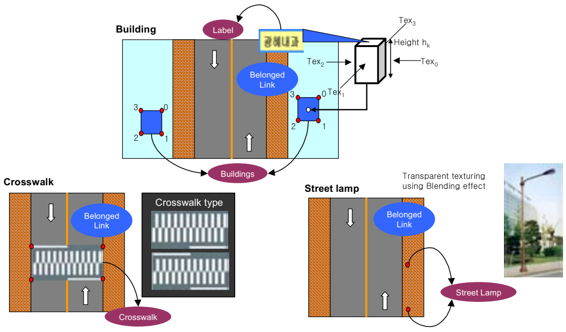

Fig. 5 Facilities - Building, Crosswalk, Street lamp

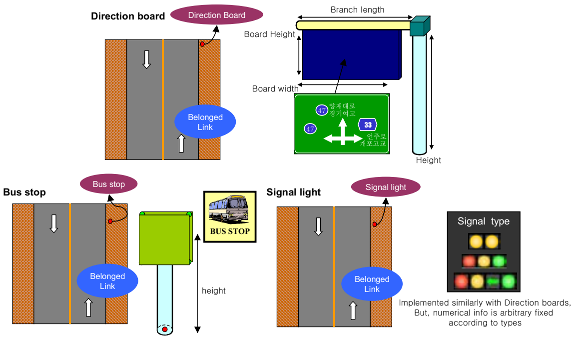

Fig. 6 Facilities - Direction board, Bus stops, Signal light

Finally, we have constructed roadside trees and manholes as shown in Fig.7. These extra facilities are arbitrary located, but drawn to stand in a straight line using fixed sizes and distance.

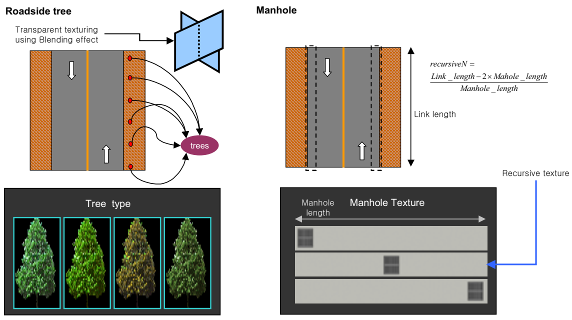

Fig. 7 Extras-Roadside tree, Manhole

3.4 Entry node & Dummy node

In node data file, there are two exceptional forms that represent entry and dummy node. Data structure and graphical outlines are shown in Fig. 8. Entry node means outer border of the test area so that there are only Node ID and indicator. And, dummy node data set, which is used for the creation of curved links by connecting two links, contains five vertexes, median strip and lane information.

Entry node(only ID assignment)		
Node ID	Indicator(entrynode)	0

Dummy node: Connection between links to be curved							
Node ID	indicator (dummynode)	Total of coordinates (n, usually n=5)	n-coordinates	Median strip		Lane-dividing line	
			$(x_1,y_1)\cdots(x_n,y_n)$	Type	Width	The number	Width

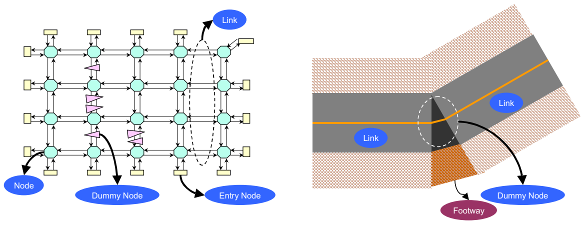

Fig. 8 Entry node & Dummy node

3.5 Camera path and animation

To offer realistic navigation scene to traveler, we give driving animation effect by generating viewpoint's path using Bezier curve equation as shown in Fig. 9 and set the viewpoint position, camera's position and up vector like Eqs. (1)~(5). The arriving point of a link animation has to be exactly positioned to the departure point of next node animation, and also in the reverse case likewise.

$$C_1 = -k \cdot \frac{\overrightarrow{M_1M_2}}{\left\|\overrightarrow{M_1M_2}\right\|} + C_2 + (0,0,h) \tag{1}$$

$$C_2 = (1-t)\left(M_1 + k \cdot \frac{\overrightarrow{M_1M_2}}{\left\|\overrightarrow{M_1M_2}\right\|} \right) + t \cdot M_2 \tag{2}$$

$$C_1 = (1-t)^2 \left(S_1 - k \cdot \frac{\overrightarrow{M_1S_1}}{\left\|\overrightarrow{M_1S_1}\right\|} \right) + 2 \cdot (1-t) \cdot t \cdot CP_1 + t^2 \cdot S_2 + (0,0,h) \tag{3}$$

$$C_2 = C_1 + k \cdot \frac{\overrightarrow{C_1C_{1\_previous}}}{\left\|\overrightarrow{C_1C_{1\_previous}}\right\|} - (0,0,h) \tag{4}$$

$$\overrightarrow{C_u} = \frac{h^2}{k^2+h^2} \cdot (C_2 - C_1) + (0,0,h) \tag{5}$$

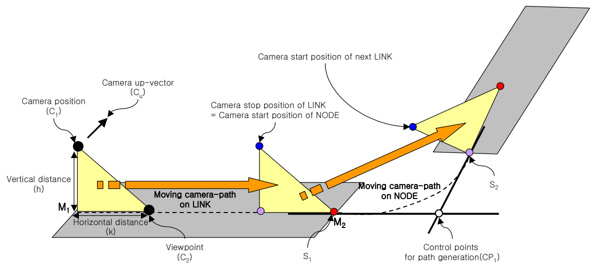

Fig. 9 Camera path on Link and Node

Fig. 10 represents how the streets are finally displayed and what kinds of functional buttons we can operate. We can select Link or Node ID and set parameters such as window frame size, camera's position and translation speed, which are related with driving animation and AVI-file creation. These created files by graphic engine are listed and stored in web server.

Fig. 10 The appearance of graphic engine

4. SERVICE DEMO

In this chapter, our demonstration service on web site is introduced. As shown in Fig. 11, there are three sub screens for 2D site map service, front directional board display, and 3D navigation display. We can check turning direction in the next node and control our navigation using animation control keys.

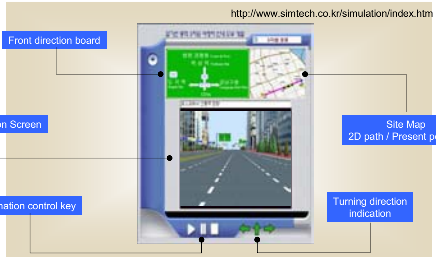

Fig. 11 Screens and functional buttons on the web service

Fig. 12 shows operation steps of the service scenario. When traveler selects departure and destination place such as a subway station or a well-known hospital or a building, 2D site map screen displays the shortest path between them. If a 3D transformation button is pushed down, web page displays all screens and we can refer more detail information such as present position of navigating camera, road conditions including neighborhood facilities, front directional board, which helps traveler's decision of driving direction. Investigating 3D street information of a certain place in advance, traveler can drive familiarly even if it was his first trip to there.

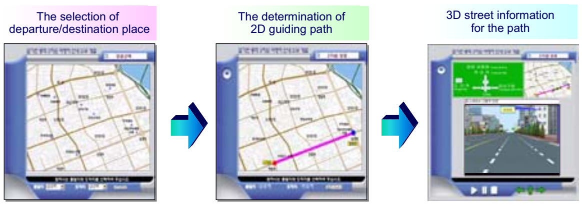

Fig. 12 Operation steps

5. CONCLUSION

In this paper, we have introduced a web-based traveler guide service and its demo scenario. Client users have been able to get detailed street information in 3D and take a test trip with driving animations. The most difficulty of this research was to acquire road information such as lanes, roadway width, pockets, etc, from present GIS DB. Therefore, we needed to construct generalized structures of road traffic data as well as to develop a graphic engine by ourselves. To reduce the load of web-server, however, effective video compression or web 3D techniques has to be considered as a future work. In addition, GIS data should be automatically extracted from present GIS database over larger areas. Now, as a continuation of the research, we will try to integrate this service with present wireless communication products to propose mobile solutions.

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