# Modeling of Roads for Vehicle Simulator Using GIS Map Data

**Hyung-Eun Im[1,#], Won-Suk Sung[2], Won-Gul Hwang[1], Kageyama Ichiro[3]**

1 School of Mechanical Systems Engineering, Chonnam National University, Gwangju, South Korea
2 Graduate School, Dept. of Mech. Eng., Chonnam National University, Gwangju, South Korea
3Dept. of Mech. Eng., College of Industrial Technology, Nihon University, Japan
# Corresponding Author / E-mail: heim@chonnam.ac.kr, TEL: +82-62-530-1924, FAX: +82-62-530-1689

KEYWORDS : GIS, Digital Map, Vehicle Simulator, Direct-X, Texture Mapping, DXF(Drawing eXchange Format)

*Recently, vehicle simulators are widely used to evaluate driver's responses and driver assistance systems. It needs much effort to construct the virtual driving environment for a vehicle simulator. In this study, it is described how to make effectively the roads and the driving environment for a vehicle simulator. GIS (Geographic Information System) is used to construct the roads and the environment effectively. Because the GIS is the integrated system of geographical data, it contains useful data to make virtual driving environment. First, boundaries and centerlines of roads are extracted from the GIS. From boundaries, the road width is calculated. Using centerlines, mesh models of roads are constructed. The final graphic model of roads is constructed by mapping road images to those mesh models considering the number of lanes and the kind of surface. Data of buildings from the GIS are extracted. Each shape and height of building is determined considering the kind of building to construct the final graphic model of buildings. Then, the graphic model of roadside trees is constructed to decide their locations. Finally, the driving environment for driving simulator is constructed by converting the three graphic models with the graphic format of Direct-X and by joining the three graphic models.*

Manuscript received: September 9, 2004 / Accepted: December 29, 2004

## 1. Introduction

GIS (Geographic Information System) is a total information system to assists in decision-making as integrated system of geographical data. The system is designed to collect, store, search, manipulate, analyze and visualize various type of geographical information.[1] The geographical information consists of spatial data to describe topography and buildings, and non-spatial data such as traffic volume. The national standard of digital map is NGIS (National Geographic Information System)[12], and has a reference point at National Geographic Information Institute. It is in DXF (Drawing eXchange Format)[12, 13] file of AutoCAD. The topography and buildings of national standard digital map of NGIS are given their own identification codes by their attributes.[3] They are classified and stored on a layer with the same name of its own code. Many studies for land management system, road management, road network, and vegetation have been performed using the GIS[2~11]. The GIS is applied in diverse fields such as government facilities, electricity, gas, and water/waste water management system, and Location Based System (LBS).

In this study, a virtual driving environment for a driving simulator is constructed with location information of road, roadside buildings, traffic signal, and roadside tree from spatial data of GIS. To convert road information into Direct-X format, the graphic data is constructed using AutoCAD and 3D Studio MAX. To give feeling of speed, mesh model of the road is constructed with a constant length. After that, texture mapping technique is utilized to guarantee reproduction speed of graphic.

To construct driving environment, data for roads and buildings are extracted from the digital map of GIS, and preprocessed to be suitable for construction of virtual environment. Models of roads are constructed with meshes of constant length and width, and buildings are modeled as solids which have base areas and heights. The graphic environment model is constructed from mesh models of roads and solid models of buildings generated with texture mapping technique. Finally, the virtual driving environment for the vehicle simulator is constructed by adding roadside tree to the generated graphic environment model.

The driving environment constructed using spatial data of GIS has topographical information, it can be applied to 3D GPS, LBS, and so forth. It is also applicable to analysis of traffic volume, because it describes real road network. It has so many applications, for example, analysis of city environment by manipulating GIS data, such as spacing between buildings, heights of buildings, and widths of roads.

## 2. GIS road information

The GIS contains information of the real world, and as a result so many necessary data can be extracted by careful manipulations. To describe lots of information systematically on a map, the digital map has many layers which contains buildings, topography, signs, symbols etc. Users can add new layers, if necessary.

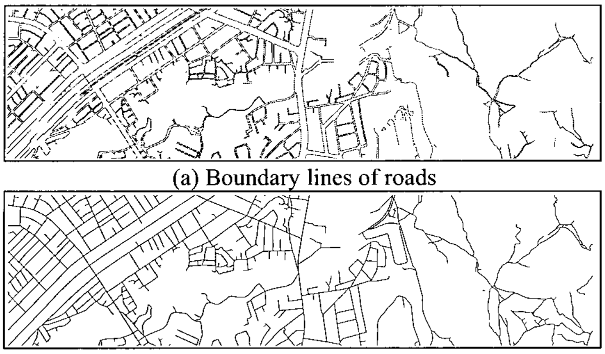
### 2.1 Constitution of road information

In the road law, road is defined as a boundary line of the driving lane. In the spatial data of GIS, the road is one of facilities, and classified as national highway road, general national road, capital road, metropolitan road, local road, city road, and district road. The name of road layer begins with prefix "AD[12]." Information on the width of road, the number of lanes, traffic signals, roadside buildings are being updated continually.

Road consists of its boundary line and centerline. The boundary line of road gives information for location and width of roads, and location of roadside facilities, so it can be used in various fields such as management of facilities, planning of transportation, and so on. Intersections of the centerlines and other important points on the centerlines are defined as nodes, and centerlines and nodes constitute road network. In the spatial data of GIS, the road information is important geographical feature, and is used in traffic analysis such as traffic management, and optimal path decision.[6]

### 2.2 Correction and adjustment of road information

To construct the virtual driving environment for a vehicle simulator, information of roads such as boundary lines, centerlines, lanes, and roadside data are required.



(a) Boundary lines of roads

(b) Centerlines of roads

Fig. 1 Boundary lines and centerlines of roads

The boundary lines extracted from the map data of a part of Seoul are as shown in Fig. 1(a). Local narrow roads are ignored for simplifications. Boundary lines of roads are sometimes not consistent. They are sometimes overlapped with boundaries of buildings and omitted in some cases. Connection to consecutive roads can be incomplete. Hence the omitted boundary line must be completed on the basis of centerlines. Overpasses and underpasses are categorized differently, and saved in different layers.

A centerline of a road in the digital map is a half line along the center of a pair of boundary lines, as shown in Fig. 1(b), and does not coincide with the painted line on the actual road. The spatial data of GIS has information of centerlines, but no information for painted centerlines and lanes. Therefore, local narrow roads are ignored, and centerlines of the other roads are defined according to the number of lanes.

The number of lanes is generally determined by the width of road. The distance from the centerline to each boundary line is defined as the width of a road. The width of the road is divided into several lanes with maximum of 8 lanes, and the result is stored in different layers.

## 3. Construction of Road for Simulator

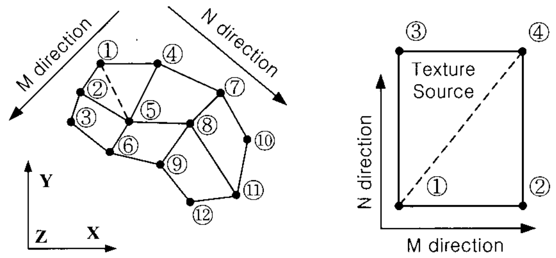
### 3.1 Mesh model of road

Texture mapping technique is used for construction of environment of vehicle simulator. To use texture mapping, it is necessary to prepare mesh model to make appropriate shape with certain pattern, which is capable of manipulating shadow and rendering.

The mesh model of a road consists of several meshes with the same width as the road constructed on the basis of the centerline composed of straight line and curved line. The mesh model of a road is constructed with meshes of constant length. It gives a feeling of speed in virtual environment. The constant width of a road gives a realistic visual effect during steering, lane changing, and turning.

Polygon mesh in the M and N directions is constructed with commands such as PFACE, 3DMESH of AutoCAD, as in Fig. 2. The polygon mesh model of Fig. 3(a) consists of 6 meshes, and has 4 division lines in M direction and 3 in N direction. In case of the mesh □ ①②⑤④, a line ①② is in the M directional axis, and the direction perpendicular to this line becomes N directional axis.

By texture mapping technique, the texture source of Fig. 3(b) is mapped to surfaces △①②⑤, △①⑤④ of polygon mesh as shown in Fig. 2(a). Thus, divided texture sources △①②④, △①④③ of Fig. 2(b) is mapped to surfaces △①②⑤, △①⑤④ of Fig. 2(a), by magnification or reduction. If the width of mesh is not constant, texture can be distorted. If length of mesh is not constant, the length of lane does not become constant. As a result, feeling of driving speed can be lost. So, the width and length of mesh must be selected from considering the width of a road, and the spacing of white lane mark.




(a) Polygon mesh (b) Texture source

Fig. 2 Mesh schema

### 3.2 Straight part of a road

The straight part of a road is shown in Fig. 3, which has start point $P_s(x_s, y_s)$, end point $P_e(x_e, y_e)$, and slope $\theta$ with respect to X-axis. To make mesh model of straight part of a road, the number of meshes and coordinates of mesh points must be determined.

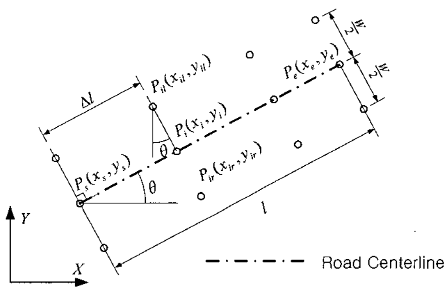



Fig. 3 Mesh points of a line

If the length of mesh is $\Delta l$, the number of meshes for straight road of length $l$ becomes $[l/\Delta l]+1$, where [n] is the largest integer less than n. The coordinates of point $P_i$ distance $\Delta l$ away from start point is as follows:

$$P_i = (x_s + i\Delta l\cos\theta,\ y_s + i\Delta l\sin\theta) \tag{1}$$

From the coordinates of point $P_i$, coordinates of left and right points of mesh points, width $\pm\ w/2$ away perpendicular to centerline, become

$$P_{il} = (x_i - \frac{w}{2}\sin\theta,\ y_i + \frac{w}{2}\cos\theta)$$
$$P_{ir} = (x_i + \frac{w}{2}\sin\theta,\ y_i - \frac{w}{2}\cos\theta) \quad (2)$$

When all coordinates of mesh points on the straight part of a road are determined, those points are connected by certain rule to generate mesh model which is capable of texture mapping.

### 3.3 Curved part of a road

In the digital map of GIS, the curved line is defined as an arc with center $P_c(x_c, y_c)$, start angle $\theta_s$, end angle $\theta_e$, and radius $R$ as in Fig. 4. The number of meshes for the curved part of a road is $[l/\Delta l]+1$. The point $P_i(x_i, y_i)$ length $\Delta l$ away from start point of an arc is as follows:

$$P_i = (x_c + R\cos\theta_i,\ y_c + R\sin\theta_i) \quad (3)$$

where $\theta_i = \theta_s + i\Delta\theta$.

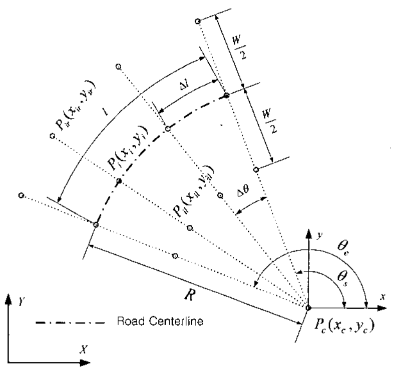
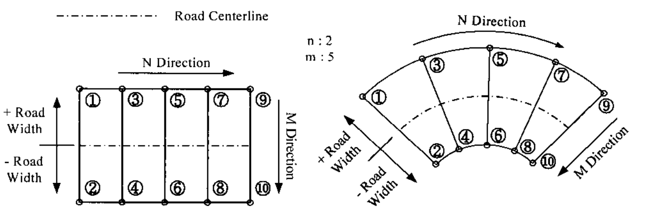



Fig. 4 Mesh points of an arc

After determining coordinates for point $P_i$ on an arc, coordinates of left and right points, width $\pm\ w/2$ away in the radial direction, become

$$P_{il} = (x_i + \frac{w}{2}\cos\theta_i,\ y_i + \frac{w}{2}\sin\theta_i)$$
$$P_{ir} = (x_i - \frac{w}{2}\cos\theta_i,\ y_i - \frac{w}{2}\sin\theta_i) \quad (4)$$

Using mesh points obtained from Eq. (2) and (4), the number $m$ and $n$ must be decided to generate mesh models of the straight and curved parts as shown in Fig. 5. The number $m$ is the number of lines of **M** direction, and the number $n$ is of **N** direction, in the polygon mesh. As in Fig. 5, if the number of mesh points is 10, and $n$ is 2, then $m$ becomes 5 which is the quotient of division of mesh points by $n$.

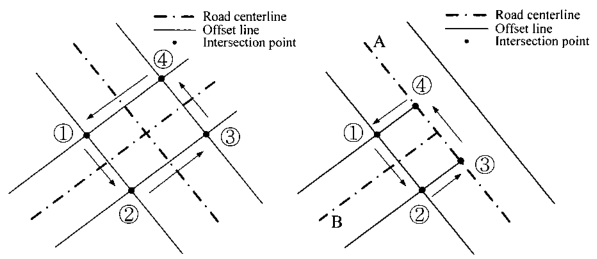



(a) Entity type : LINE (b) Entity type : ARC

Fig. 5 Generation of polygon mesh

### 3.4 Road intersection

Road intersection is an important element in the construction of roads. The actual road intersections have various shapes according to topography, but the information of roads in the spatial data of GIS is restricted. In this study, models of road intersection are assumed to have 4 intersection points.




(a) Cross roads (b) Three-forked road

Fig. 6 Polygon schema of intersection area

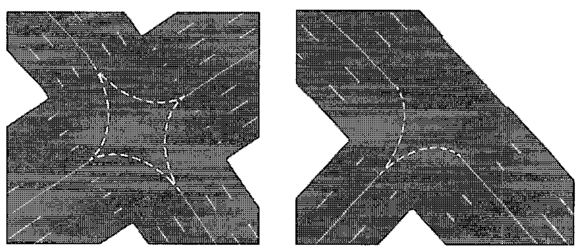
In the simplified model of road intersection of 4 roads as shown in Fig. 6(a), 4 parallel lines obtained by offsetting the half of road width away from each centerline give 4 intersection points ①, ②, ③, ④. These 4 intersection points are connected counter clockwise to make a polygon, and the generated polygon is saved in a new layer. In case of road intersection of 3 roads, the intersection of two parallels obtained from offsetting centerline *B* and centerline *A* give 4 points as shown in Fig. 6(b), and a polygon is generated as before.

The data for mesh model generation of road intersection is extracted from these generated polygons, and new layer for road intersection is defined. Coordinates of vertices and start point are determined from each polygon. On the layer of road intersection, a single mesh for each polygon is generated with its local coordinates. The local coordinates of the mesh are chosen, so that line $\overline{①②}$ becomes M axis as shown in Fig. 6, and the point ① is taken as a start point.

### 3.5 Construction of road

To construct the final graphic model of the road for a vehicle simulator, road images is necessary to map to mesh model of road. The lane marks are dashed white lines with constant space, and are important elements to give a feeling of speed. Therefore, lane mark images of road must be made appropriately.

In this study, the road images are made according to road law which states that the length of dashed white lane mark is 3m, their space is 5m, and the width of yellow and white lane marks is 0.1m. Digital photographic images of actual road are used for the colors of white and yellow lane marks. Photographic images of road surfaces are taken and used to distinguish various types of roads. After image processing, samples of various road surface are made. The number of lanes is determined from the width of the road.



(a) Cross road (b) Three-forked road

Fig. 7 Graphic model of roads

The final graphic model of road is constructed by texture mapping technique with road images and road intersection images, as shown in Fig. 7.

GIS has no information about road slope, pavement condition, and surface roughness of road. Therefore, we assumed zero slope and zero roughness for road. As a result, the simulation for vehicle dynamic characteristics test on flat road is possible, but the simulation on nonzero road slope and other road surface roughness is not possible.

## 4. Roadside Environment and Vehicle Simulator

To give reality to road for simulator, it is necessary to construct a roadside environment, such as roadside buildings, trees, and traffic signals, and so on. The spatial data of GIS has no information for locations of roadside tree, traffic signal, and height of building. Therefore, heights of buildings are decided according to their use and characteristics. Locations of roadside trees are arranged, and traffic signals are not considered at this stage of study.

### 4.1 Buildings

In the spatial data of GIS, buildings are categorized as facilities. They are divided into 146 kinds, such as house, tenement house, and government building, etc. The spatial data has only their occupation area information, not their height information. Generally, a story of building is recognized as the number of windows in vertical direction, so the story of buildings is decided according to their occupied area which is calculated from the spatial data. Images of many different story buildings are prepared according to their use and characteristics. From poly line that describes boundaries of building, the area of the building is calculated. According to the area and the sort of building, its height is determined, and its number of story is decided assuming 3.5m of a story height.

A house is assumed to have maximum 4 stories and apartment buildings and others are maximally 15 stories according to their base area. Various images of buildings are mapped to the generated solid models of buildings according to their stories and sort using the texture mapping technique as shown in Fig. 8.

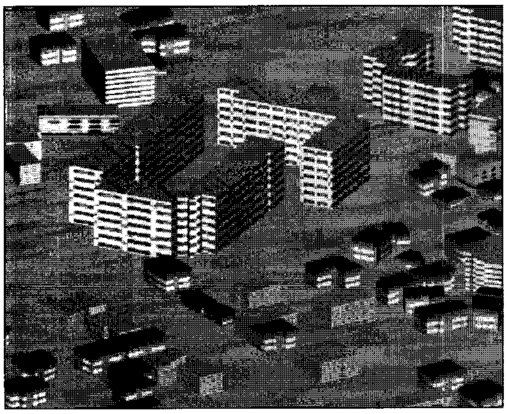


Fig. 8 Graphic model of buildings

### 4.2 Roadside trees

Trees along the road area are important factors to consider in order to give a feeling of speed to a driver like dashed white lines. In this study, a program was developed to decide locations of trees and store their location data in ASCII format file. Using these data file of tree location, the vehicle simulator can show three kinds of tree images at designated locations during the driving simulation.

### 4.3 Vehicle driving simulator

A vehicle driving simulator receives information about steering angle, pressure of brake pedal, and opening of throttle valve from test vehicle. It makes possible to perform a virtual driving test by transferring the driving environmental image to a driver through CRT projector

The control system of vehicle simulator consists of 8 modules for the sake of efficiency and future expansion of the system. There are eight modules to implement a virtual driving environment, including three graphic modules. They are vehicle graphic module, a road graphic module, and an environment graphic module of buildings and roadside trees, etc. Other modules are sound module, vehicle dynamics module, driver module, interface module, and expansion module.[7]

Developed driving environment is called by graphic modules developed with direct-X. Roadside environment around a driving vehicle is shown according to location information of the vehicle. This can be seen at various viewpoints and view angles of an observer. Fig. 9 shows environment images from the various view points. From the viewpoint of a driver, a driver can feel appropriate speed with the aid of centerline, roadside trees, buildings, and some inside view of the vehicle. But other driving vehicles on the road are not considered yet, and the exterior view of buildings does not have its own look according to their use and characteristics. Almost scenes of road surface do not give reality yet. These problems must be fixed step by step in the future study.

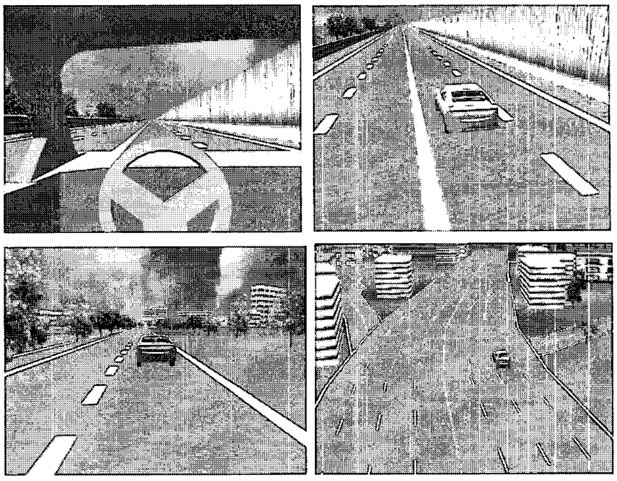


Fig. 9 Environment of vehicle simulation

## 5. Conclusions

After extracting road and roadside data from the GIS data file, they are modified and preprocessed. The road mesh models with uniform length and width are generated using the data. The road intersections are also defined and their mesh models are constructed.

The graphic model of roads is constructed by texture mapping to these mesh models of roads and intersections. For the construction of roadside environment, 3D solid building models are generated with various heights according to their use, characteristics and base areas obtained from the spatial data of GIS. Coordinates of roadside trees are saved into ASCII format file, and it is easy to edit them and make use in virtual environment.

As a result of applying the constructed driving environment to the vehicle simulator, it was possible to feel appropriate speed and three-dimensional effects. But it is not real enough due to lack of various images of buildings and road surface, and absence of traffic signals and other vehicles. Therefore, the study on the various road surfaces and roadside environments is necessary in the future.

Road environment constructed from the information of GIS has precise topographical location information, so it can be used in 3D GPS and LBS and it is expected to applied in analysis of traffic volume and city environment, and so on.


## ACKNOWLEDGEMENT

This study was supported by the grant of 2001 BK21 Project.

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