Highway Sequence Editor
Based on the Length-based Highway Product Model

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Summary

The highway product model based on the length information of the centerline, and the application system is developed. This paper shows the schema and the modeling process of the product model, which includes geometric elements such as an alignment, lanes, sidewalks, shoulders and sprits, and accessories such as guard fences, plantings and signs. Furthermore, The Highway Sequence Editor (HSE) is developed as an application system to verify the model.

1 Introduction

Highway alignments are designed as the sequence of elements such as tangents, arcs and clothoids on the 2-D plans. This method makes the difficulty to build and edit the 3-D highway models on CAD systems, because horizontal/vertical alignments and cross-sections are determined individually and each kind of elements has different parameters (AASHTO, 1994). The conventional method is adopted as the alignment system also in the developed road product models (ex. OKSTRA, 2001; Autodesk, 2003) in recent years. To solve these problems, the previous study by Makanae(2002a,b) proposed the parametric highway-modeling method based on the length of the centerline of the highway. This paper shows the schema of the highway product model and the modeling system based on this method.

2 Parametric modeling of highway alignments

2.1 Functionalization of highway alignments

The horizontal trajectory of a traveling vehicle is determined by variation of velocity with time and variation of curvature by steering. The vertical trajectory depends on variation of velocity and gradient with time. On the assumption of a vehicle traveling at constant velocity, Time-velocity-curvature and time-velocity-gradient systems can be regarded to be equivalent to length-curvature and length-gradient systems. Functions with horizontal length along a highway alignment as a parameter in each system are defined as the curvature and gradient functions. These functions can be represented by continuous piecewise linear functions, and can be specified by the boundary conditions of curvature and gradient functions(Makanae, 2002a,b).

2.2 Curvature function

The trajectory of an automobile traveling on a plane at a constant velocity with the steering wheel set at a fixed angle has a constant curvature regardless of the trajectory length, and draws a straight line or a circular curve. In the case where the driver turns the steering wheel at a constant angular velocity, the trajectory draws a curve with the curvature either increasing or decreasing in proportion to the trajectory length traveled. Such a curve is known as the clothoid. A horizontal alignment, which is a series of the above elements of an alignment, can, therefore, be represented by a function of curvature varying with time or trajectory length. Here, a function representing variations of curvature based on trajectory length l is expressed by curvature function C(l).

A clothoid used for a transition curve assumes the turning of the steering wheel at a constant speed. Then, the rate of change in curvature remains unchanged. If the rate of change in curvature is represented by k_c, $C(l)$ for trajectory length l can be represented by a linear expression as shown by equation (1):

$$C(l) = k_c\, l + c_s \tag{1}$$

Where, c_s is the initial curvature.

Equation (1) can also represent a straight line or a circular curve. A driver traveling along a continuous highway alignment turns the steering wheel continuously. Then curvature function C(*l*) becomes also continuous. C(*l*) may thus be regarded as a continuous piecewise linear function(Figure 1).

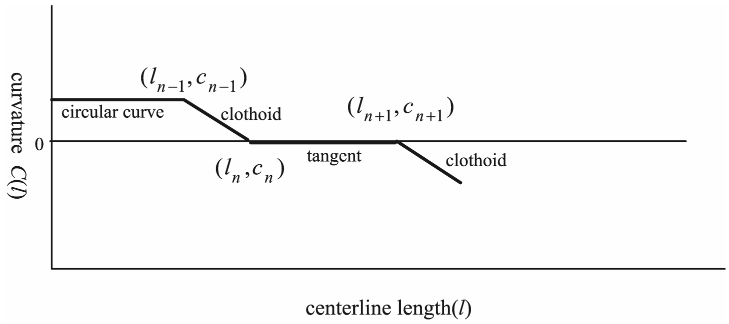

Figure 1 Curvature function

2.3 Gradient function

For existing design methods, elements of a vertical alignment consist of straight lines and vertical curves. For vertical curves, parabolic curves are generally used. Gradient, which is a differential of vertical alignment, is then represented by a linear expression. Gradient function *I*(*l*) can be represented by equation (2):

$$I(l) = k_i\, l + i_s \tag{2}$$

where, k_i is the rate of change in gradient, i_s is the initial gradient and l at the origin is assumed to be 0.

Since vertical gradient is continuous as well as horizontal alignment, gradient function *I*(*l*) is continuous, and can be handled as a linear function piecewise(Figure 2).

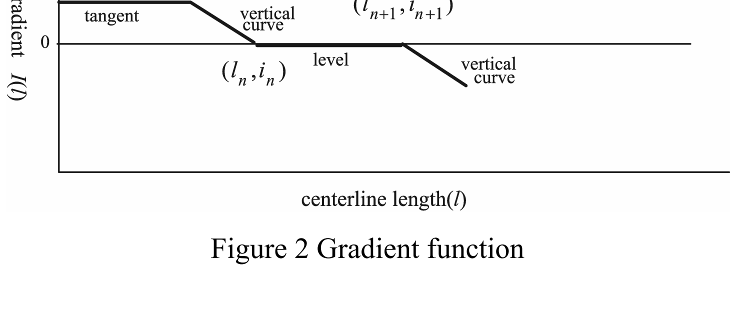

Figure 2 Gradient function

3 The length-based highway product model

3.1 Schema of the length-based highway product model

The schema of highway product model based on the parametric highway alignment is shown in figure 3. This model includes the geometric elements such as an alignment, lanes, sidewalks, shoulders and sprits, and accessories such as guard fences, plantings and signs.

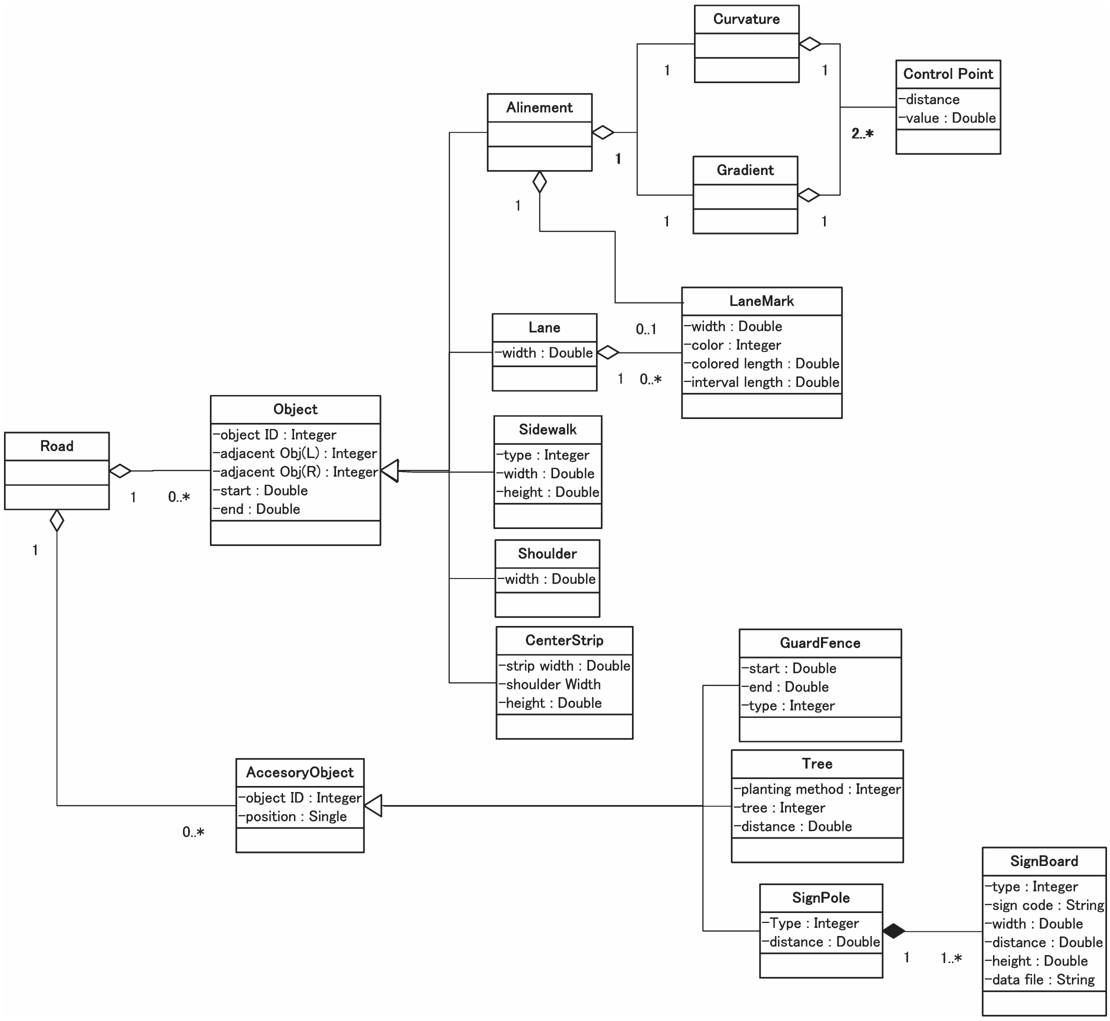

Figure 3 The schema of highway product model

3.2 Process of the 3-D geometric modeling

By the control points for curvature and gradient functions, 3-D coordinates of the highway alignment can be defined. As initial values, such as design speed, a standard cross section profile and standard crossfall are defined, the 3-D geometry of the highway can be constructed automatically. The 3-D modeling process of the highway is shown in Figure 4.

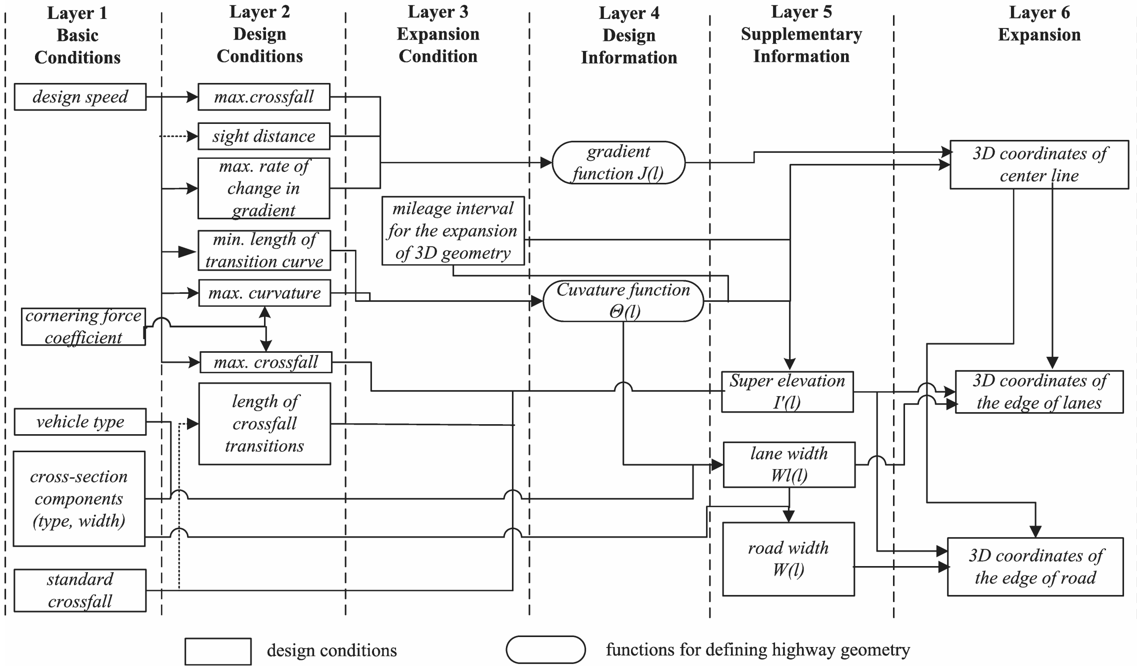

Figure 4 3-D highway modeling process

The modeling process of the 3-D highway geometry can be classified into 6 layers..

-Layer 1 provides the most basic information on the highway to be designed, and define the objects specs suchas design speed, design vehicle, basic lane and sidewalk width, basic shoulder width, basic cross slope, etc.

-Layer 2 provides conditions for defining the curvature and gradient functions that define the alignment.

-Layer 3 shows conditions that define the conditions for expanding curvature and gradient functions.

-Layer 4 provides data that define curvature and gradient functions, backbone of the geometric design defined by the design engineer, which are the boundary conditions of the functions.

-Layer 5 provides preliminary data for defining a geometric design based on the highway alignment defined in Layer 4. The data are obtained automatically.

-Layer 6 shows the results of expansion to the design space of the highway geometric design built based on the data defined in Layers 4 and 5.

4 Development of the Highway Sequence Editor

The highway product model schema is based on the length information of the centerline of highway. Information of alignments and cross-section objects can be determined to the length of the centerline subordinately. Applying this concept, the highway CAD system in this study is developed. The system image is shown in figure 5.

This system is named “Highway Sequence Editor (HSE)”, because this system image is similar to computer music software which can design the sound in the time sequence. The system is developed for and under the Windows XP operating system using Visual Basic 6.0 and OpenGL graphics library. The data model of the product model described by UML is mapped to the XML document.

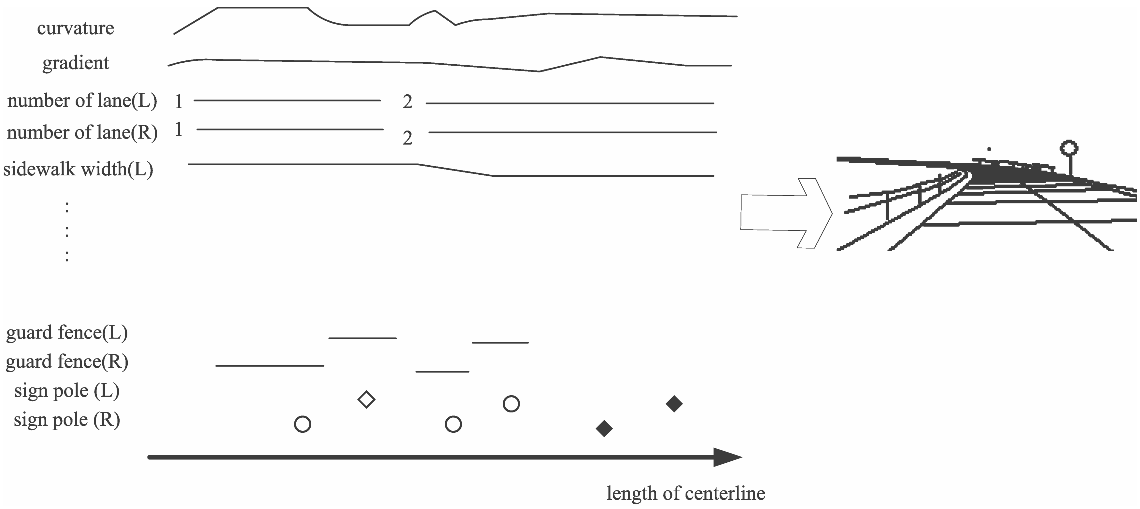

Figure 5　An image of the HSE

Figure 6 shows the interface of the HSE. The input area has some windows in which a designer can determine the curvature / gradient functions, the lane numbers, the widths of sidewalks, and the positions of plantings and signs.

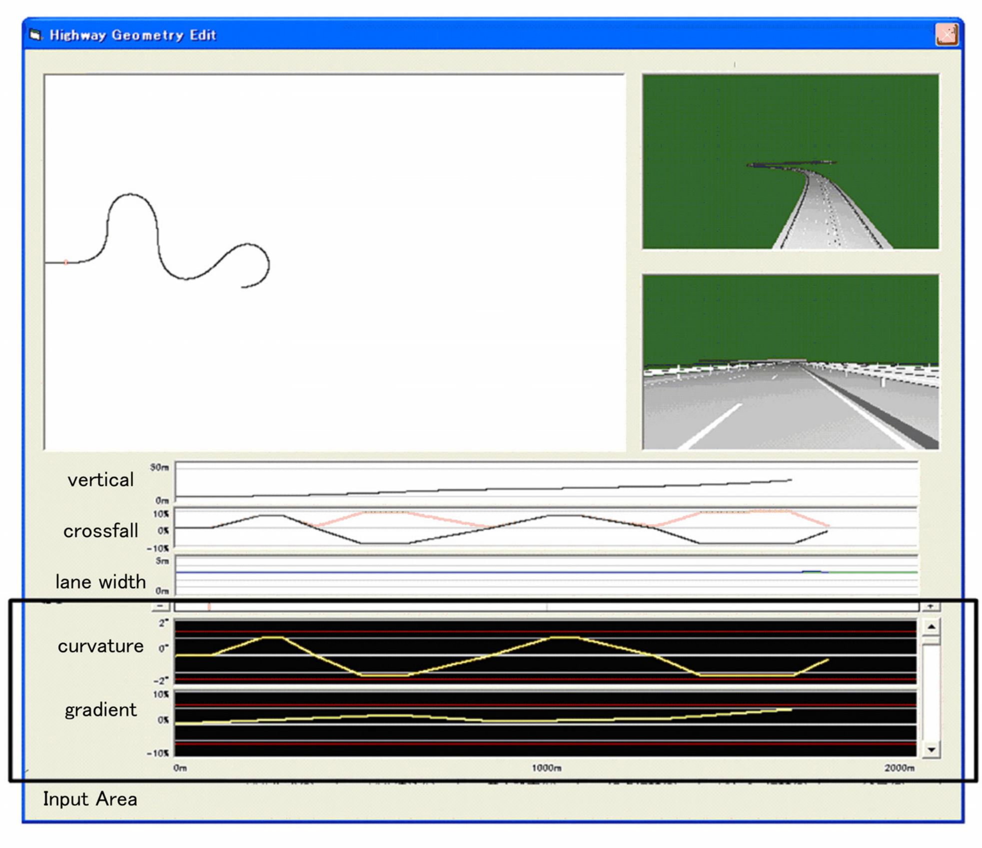

Figure 6　An interface screenshot of the HSE

5 Conclusions

The 3-D highway product model based on the centerline length is developed in this study. This model can simplify the architecture of the data model by making length information into a standard.

The 3-D highway modeling system HSE is developed to verify the model. The system can build the 3-D geometry automatically by determination of the default values of the parameters such as design speed and changes of curvature, gradient and the cross-section profile. It proves the highway product model in this study is valid. In order to make the model and the system practical in the near future, the more development and verification are required.

Although the product model in this paper aims at the use for a design, it can consider application to an intelligent transport system as other application, because this model can provide curvature and gradient data that is required to control the automated vehicles.

6 References

Autodesk, Inc. (2003): http://www.landxml.org.

ASSHTO(1994): A Plicy on Geometric Design of Highways and Street, AASHTO.

OKSTRA(2001): Objektkatalog für das Straßen- und Verkehrswesen, http://www.okstra.de/.

Makanae, K. (2002a): Functionalization of Highway Alignment for Computer-Based Design, Proceedings of the 9th International Conference on Computing in Civil and Building Engineering, pp.877-882.

Makanae, K. (2002b): Highway geometric modeling method by curvature and gradient functions, eWork and eBusiness in Architecture, Engineering and Construction(European Conference of Product and Process Modeling 2002 Proceedings), pp.463-464.