Building Virtual Roads from Computer Made Projects

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Abstract. Driving simulators require extensive road environments, with roads correctly modeled and similar to those found in real world. The modeling of extensive road environments, with the specific characteristics required by driving simulators, may result in a long time consuming process. This paper presents a procedural method to the modeling of large road environments. The proposed method can produce a road network design to populate an empty terrain and produce all the related road environment models. The terrain model can also be edited to produce well-constructed road environments. The road and terrain models are optimized to interactive visualization in real time, applying all the stet-of-art techniques like the level of detail selection. The proposed method allows modeling large road environments, with the realism and quality required to the realization of experimental work in driving simulators.

Keywords: Driving simulation · Immersive environments · Procedural modeling · Road environments

1 Introduction

Driving simulators come up as a very important scientific tool for the realization of immersive experimental studies in different areas, like psychology, ergonomics, and roadways engineering.

In psychology, they are used to develop research related to the driver behavior. An example is the evaluation of interference in the primary driving task, of a secondary task like the use of mobile phones, navigation systems or traffic information systems. The driving simulators are also used in ergonomics to study “In Vehicle Information Systems” that interact with the driver, like navigation systems (GPS) or mobile phones. In roadways engineering, they are used to analyze road paths in design stage, but also real roads, allowing the test with real drivers. For example, the study of factors that conducts to dangerous driving or, in traffic engineering, the study of dangerous

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overtaking maneuvers with frontal collision probability, in roads with two lanes (one in each direction) without compromising the driver's safety.

Driving simulation experiments require the creation of extensive road environments with high level of quality, and road models prepared to visualization in real time. The creation of road models with the expected level of quality requires previous definition of the road networks and the road paths. The roads network and road path definition can be obtained through the procedurally method presented in [1]. Alternatively, the generation of models from road paths obtained by road design specialists [2], can result in a long time consuming task. After obtaining a road path it is still necessary to produce the road model and edit the surrounding environment. There are some automatic modeling tools, like the one presented in [3], which allow the efficient generation of the road models from road path definitions. These known tools can provide an important help in the road environment preparation but they are mainly focused in single roads and they cannot produce complete environments of roads networks.

This paper presents a method that allows to automatically generate models of road networks from road paths. The produced models are suitable to the implementation of immersive driving simulation experiences for scientific purposes. The work presented in this paper focuses in the generation of virtual road networks and terrain edition, as illustrate in Fig. 1.

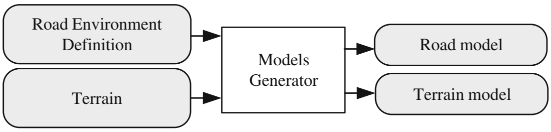

Fig. 1 Generation of geometric models

The applied road environment definition includes the specification of horizontal and vertical alignments, the 3D position of each of road path vertices, and the road surface orientation for each segment in every road [4]. The coordinates of the vertices are calculated considering the altimetry and cross-slope data of the road, producing road models similar to those found in the real world. To optimize the real time visualization, a space organization was considered and each element is hierarchically defined in different levels of detail (LOD) [5]. The model preparation also involves calculating the texture coordinates in the road triangle-strip, to produce more realistic models. The modeling process also needs to adjust the definition of the terrain in order to provide a complete well-constructed environment.

This work provides an important contribution to the procedural generation of realistic road environments aimed to virtual simulation applications.

2 Virtual Roads

The driving simulation requires visual models of road environments, usually composed from sets or strips of elementary polygons. These models can be done from the definitions of road paths, for example, by the procedural method presented in [1]. The road path represents the road trajectory over the terrain model and can be defined by a sorted list of straight segments. So, it can be fully represented by the coordinates of interconnection nodes between adjacent segments (Fig. 2).

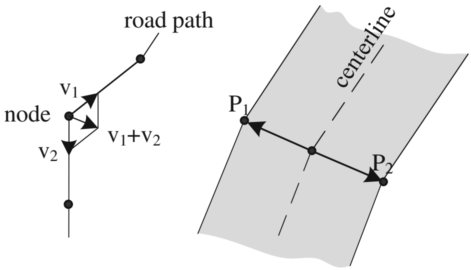

Fig. 2 Polygons vertices of the road

2.1 Road Model

The visual model of a road is obtained by stepping through the nodes of the road path and determining the polygons vertices that make up the visual model. Surfaces in graphic systems are modeled by polygonal meshes, where the triangle strip is the most common primitive. The triangle strip created along the road path fits in the data structures *TRIANGLE_STRIP* available from *OpenSceneGraph*.[1] Using vector calculus, the vertices of the polygons of the road are determined, as illustrated in Fig. 2.

As we can see in Fig. 2, the resulting vector sum of v_1 and v_2 vectors, allows determining the vertices P_1 and P_2, of the road polygons.

The cross-slope of the road is considered in the vertices polygons calculation. In road design the cross-slope is the angle (α) calculated in the curve extension. The cross-slope in curve, contributes to the increase in the security and commodity of the travel, because it allows a part of the centrifugal force to be compensated by gravity force. The z coordinate in one cross-section may vary, dependently on the altimetry and the cross-slope definition. The z coordinate of the vertex is determined from the angle α of cross-slope defined in road path design, the road width (R_w) and the altimetry Z_{road} of the road (1).

$$Z_{vertex} = Z_{road} + R_w * \text{sen}(\alpha) \quad (1)$$

[1] www.openscenegraph.org.

So, for each road node, the vertices of the polygons have a z coordinate considering the cross-slope. To optimize the road model visualization, the number of polygons generated in a straight line is smaller than in a curve, as also happens in other works [2]. After obtaining the polygonal model of the road, the next step is to map a texture. This process consists in the mapping 2D of texture coordinates for each vertex of the polygonal road model. The road model created is therefore more immersive and realistic, as showed in Fig. 3.

Fig. 3 Virtual road environments

To accelerate the rendering process in real time, the variation of the level of detail and spatial organization were considered. So, the created road model is spatially organized and represented by several levels of detail. For distant segments, only a rough definition of the road surface is displayed. The following levels of detail consider the visualization of the road and the horizontal signalization. The higher level of detail considers the entire road environment, with detailed objects. The level of detail selection is based on the distance to the observer.

The horizontal signalization is made by road marks, defining the lanes in each road segment. These marks may have different layouts: continuous, dashed or both, as illustrated in Fig. 4.

Fig. 4 Horizontal and vertical signalization

In order to improve the visibility detection, horizontal signalization models are hierarchical organized with the road models using different layers. The vertical signalization is placed in road environment by instantiating previously defined 3D objects (Fig. 4).

2.2 Terrain Model

The construction of roadways in the real world implies earthworks in the terrain where the road is implemented. The definition of the road environment model also considers the terrain specification. The terrain model must be modified to become in accordance with the related model of the road network.

A slope is the terrain surface which is located along the road and can be originated from an excavation or an embankment on the terrain during construction of a road, as illustrated in Figs. 3 and 5. Generally, the cut slope and embankment slopes have declivity of 1–1.5 (V/H) so that the stability of the ground is guaranteed [10]. In the proposed method, after generating the trajectory of the road, it is necessary to adjust the definition of the terrain to produce the final well-constructed visual model. For each point of the terrain, the minimum distance to the road is calculated and, according to this distance, the necessity to change the z coordinate of the point of terrain is evaluated. The z coordinate of the point of the terrain is not changed if it is positioned between the definitions of slopes, as illustrated in Fig. 5, for the point P_3.

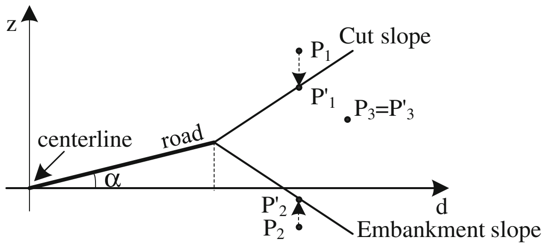

Fig. 5 Cut and embankment slope

We can also see in Fig. 5 that point P_1 is shifted down to P'_1 point, and the point P_2 is shifted up to P'_2 point. In order to optimize this process, the terrain points that are relatively far are not treated. In the edition of the terrain, the modelling information of the edited areas is registered so that, it is possible to render these areas with a different color (typically brown).

In the visualization of large terrain models, a widely used technique is to obtain more than one definition of each terrain cell through successive simplifications of its geometry [6–9]. In the visualization, the preferred representation is automatically selected, allowing to obtain optimum results [3, 5]. For large terrains, this technique, associated with the segmentation of the original model in smaller subareas, grants the best results.

3 Conclusions

The method presented in this paper allows the creation of realistic road environment models that meet the detailed standards of specification and the required performance for real time graphic systems. The presented images of road environments, were generated in the DriS[2] driving simulator using environments produced by the proposed method. The realism of the road environments was improved by the cross-slope contribution. These road environments have all the required characteristics to conduct scientific work in several fields such as psychology, ergonomics and road engineering. The resulting models allow the placement of actors and the implementation of traffic events whose effects and consequences are important to know and study [11, 12]. With this implementation, the entire environment can be obtained automatically, dramatically reducing the cost and work involved in the modeling tasks.

The generated models are optimized for visual simulation in real time and suitable for integration in driving simulators. The use of layers for the horizontal signalization, facilitates the visibility detection. The used optimization techniques allow a significant reduction of polygons in the rendering process, resulting in a fast rendering of high quality images.

In the future, large terrain visualization techniques should be further explored to maximize the quality and performance of image production in real time simulations.

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