CARTOGRAPHIC GENERALIZATION IN VIRTUAL REALITY

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ABSTRACT

This article describes the transposition of cartographic concepts to virtual reality (VR) applications. Versions of cartographic maps can be created by using Generalization. These versions can be implemented for VR applications using Levels of Detail. Cartographic Generalization is concerned with model visualization that uses twelve operators and domain-specific knowledge. There is no known transposition of these operators and knowledge to the VR realm. We present an analysis of these operators in the context of VR. A system for 3D Generalization is proposed. Artificial intelligence techniques are used for both selecting the key objects and applying the operators. This system was implemented with the JAVA language, modelled with UML and employs a MySQL database.

1 INTRODUCTION

Virtual worlds, virtual reality environments or 3D worlds can be seen as a computational metaphor of the world where people and objects can interact. They are mainly used in entertainment, games and simulators, but they are currently being used in medicine (body human study), psychology (treatment of phobias) and arts (virtual museums).

A virtual world can have many objects with varying degrees of complexity. The simplest ones are formed by a single geometric shape, while complex objects can be formed by organized simple ones. The complexity can be measured with, for instance, the number of polygons, colors and textures. Because of this complexity, user navigation in worlds with complex objects can be hampered. Renderization can be slow, causing problems in the immersion experience. Some of the main problems in the navigation in urban virtual worlds are presented in (Bourdakis, 1998), while some solutions are discussed in (Frery et al., 2002). Among the techniques that can be applied to solve the navigation problems are based on culling algorithms (Cohen-Or et al., 2000).

Generalization is a abstraction information process. In a virtual world this process may be responsible for simplifying and/or removing objects considering, for example, the user position. Generalizations are obtained with *Levels of Detail* – LODs, versions of objects in progressive levels of complexity. The LODs are usually obtained by polygon simplification; some simplification algorithms can be seen in (Luebke, 2001). There are many techniques for selecting each version or LOD (Constantinescu, 2000); the one considered here is based on the distance between object and observer.

This work deals with generalization for virtual worlds built with VRML (*Virtual Reality Modelling Language*) (WEB 3D Consortium, 2002, Ramos et al., 1997, Crossley et al., 1997). The process to generate the generalizations is not exclusive of virtual reality; it is a process used in Cartography to produce versions of cartographic maps: Cartographic Generalization.

Section 2 presents the Cartographic Generalization and its operators; section 3 presents the transposition of concepts and operators employed in cartographic generalization to virtual reality; section 4 presents the Generalization System 3D with which we validate our idea; finally, section 5 presents the conclusions and future works.

2 CARTOGRAPHIC GENERALIZATION

Cartographic Generalization may be defined as a set of proceedings applied for construction and visualization of models. This generalization aims to improve the interpretation of the information to be showed. To accomplish this task, the generalization uses operators that will be explained below.

Cartographic Generalization is employed when new maps in new scales are needed. It is concerned with the ways the information is shown (emphasizing, distributing and deleting features). This processing will depend on the cartographer's knowledge about the requirements and the desired scale.

Figure 1 presents a map generalized in two ways, the first considering the topographic features (with emphasis on the distances and number of objects), while the second considers the touristic features (enhancing important objects in the area).

2.1 Operators

To get versions of maps, cartographic generalization uses twelve operators, applied by the cartographer using domain-specific knowledge. Each operator is responsible for changing the way information is presented. These operators are presented following (Davis and Laender, 1999):

Figure 1: Generalizations (Glover and Mackaness, 1999).

OP1 - Simplification: reduce the number of vertices employed to represent the element, preserving the original appearance.

OP2 - Smoothing: displace the vertices used in the representation, in order to eliminate small disturbances and to capture the overall shape.

OP3 - Aggregation: join nearby elements.

OP4 - Amalgamation: join nearly contiguous and similar areas, by eliminating borders between them.

OP5 - Merging: join two or more parallel lines that are close to each other into a single line.

OP6 - Collapse: reduce the dimension of the representation of an object.

OP7 - Refinement: discard unimportant elements, which are close to important ones.

OP8 - Exaggeration: increase the dimensions of elements considered important for the map.

OP9 - Enhancement: increase the dimensions of symbols presents in the maps.

OP10 - Displacement: shift the position of a feature, in order to make it distinct to other ones.

OP11 - Classification: group objects which share identical or similar characteristics into categories.

OP12 - Symbolization: change objects (or categories) for symbols.

3 CARTOGRAPHIC GENERALIZATION APPLIED TO VIRTUAL REALITY

This section shows how the concepts utilized in cartographic generalization can be applied to virtual reality. First we present the transposition of operators and then how domain-specific knowledge was modelled as the rules of an expert system. Details can be seen in (Frery et al., 2003).

3.1 Cartographic Generalization Operators in Virtual Reality

OP1: these are the techniques for polygon simplification; see (Guéziec et al., 1999, Vieira et al., 2003).

OP2: image filtering (typically low-pass) and resampling in order to produce a new similar but smaller texture.

OP3, OP4, OP5: these operators can be built with a single operator in virtual reality, or as the initial stage of operators OP11 and OP12.

OP6: the result of applying OP1 iteractively.

OP7: small objects (or objects defined by the user) may not be shown in the LOD.

OP8: the scale transformation in 3D objects.

OP9: the scale transformation in 2D objects or textures.

OP10: the translation of 3D objects.

OP11: objects are grouped into categories according to their main features.

OP12: objects are replaced by symbols or icons defined by the user.

3.2 The Expert System

Expert systems simulates the behavior of the expert human for the resolution, diagnostic and analysis problems in some knowledge domain-specific (Luger, 2001).

The Cartographer builds the map generalization with his knowledge and experience about the selection objects and application of operators. We modelled the Cartographer's knowledge in knowledge rules (rules *if - then*), and they are applied to VRML virtual worlds for building the LODs or 3D generalizations. Also, unimportant objects for the theme must be discarded, so two knowledge bases were modelled: one for the selection of important objects and another for the application of operators.

4 THE GENERALIZATION 3D SYSTEM

Figure 2 shows the architecture of the system. The picture represents the real world that feeds a SIG (Geographical Information System). VRML files are generated from this input for an specif area. The Generalization 3D System is not concerned with these steps.

The *Representation Model* reads and identifies the objects in the virtual world. The input of this step are the VRML files, and objects are stored in a MySQL database. Complex objects are are defined by the DEF node in VRML, ant the classification of objects in simple or complex is automatically performed by the system.

The user classify the objects in one of three categories: *primary*, *secondary* and *indeterminate*. In the first are large

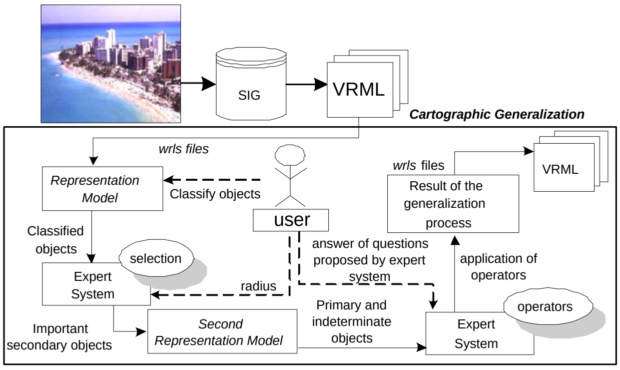

Figure 2: Generalization 3D system architecture.

objects, such as rivers and mountains. In the second are the medium-sized objects, as buildings and houses. The remaining objects are classified in the third category. The first category deals with geographic modelling, while the two others with urban modelling (Frery and Kelner, 2002). This classification is important because the operators can be applied differently according to the category.

The expert system with knowledge base about object selection works in the secondary category selecting the objects in agreement with the theme, e.g. tourism. Nothing is done on the others categories. A simple rule for objects selection is shown in Table 1: the system looks for keywords in the object name, as "museum" and "restaurant", and verifies if there are other objects near (the user gives the radius).

Table 1: Rule for secundary object selection.

1	*If* there is keyword in object name *or* there are no others secondary objects nearby *then* Select object

The *Second Representation Model* is similar to the first, but with less objects. The expert system using the knowledge base about the application of operators applies the operators to the virtual world. The system defines three levels of distance: `LOD1`, `LOD2` and `LOD3` that will be employed at distances defined by the user. Table 2 presents the LODs and their relation with the generalization operators.

Table 2: Main rules for operators application.

1	*If* `LOD1` $<>$ 0 *then* apply the simplification operator
2	*If* apply the simplification operator *and* simplify primitives *then* select the object category
3	*If* apply the simplification operator *e* simplificar `IndexedFaceSet` *then* select the object category
4	*If* simplify `IndexedFaceSet` *then* select the `IndexedFaceSet` algorithm simplification
5	*If* `LOD2` $<>$ 0 *then* apply the smoothing operator
6	*If* apply the smoothing operator *then* select the object category
7	*If* `LOD3` $<>$ 0 *then* apply the simbolization operator
8	*If* apply the simbolization operator *then* select the object category

The result of the generalization process is stored into VRML files. The system was development in Java.

4.1 The Implemented Operators

This section presents details of the implementation of generalization operators in the context of virtual reality. Our target is system validation, not the implementation of all the operators. The operators **OP8**, **OP9** and **OP10** are provided in VRML through the `Transform` node. The implemented operators were simplification, smoothing and symbolization:

Simplification: composed of two algorithms: primitive simplification and `IndexedFaceSet` simplification. The first is responsible for simplifying VRML primitives: `box`, `sphere`, `cone` and `cylinder`. A VRML primitive can be built with many faces; for instance, a sphere can be rendered with sixty faces requiring computational resources. This algorithm produces a simplified version of each primitive by projecting it onto a convenient plane. The new flat object, built as an `IndexedFaceSet`, inherits the properties of the original primitive, e.g. colour, texture and size. Spheres become circles, cones become triangles and boxes rectangles. Figure 4.1, left, presents an object built with VRML primitives and, to the right, the result of the simplification primitive algorithm. They look alike from a certain distance.

Objects built with `IndexedFaceSet` have, in most of cases, many, even millions of faces. Many of these objects are the result of exporting from 3D CAD platforms, and they are comprised of triangles. Among the papers with mesh triangle simplification one can cite (Vieira et al., 2003, Hoppe, 1996, Guéziec et al., 1999). The `IndexedFaceSet` algorithm simplification reduces the number of faces of the original object.

Smoothing: this operator works on textures with image processing techniques. The target is to get new similar smaller textures in two steps: applying a low-pass filter (Lim, 1989) to blur the image and then sampling it. Figure 4 presents an example of this operator; the image to the left is the original image, top right is the blurred one and bottom right is the subsampled one. Their sizes are, respectively, 118kB, 52kB and 12kB. The subsampling rate is $1 \div 3$.

Symbolization: this operator changes the objects for symbols which, in turn, are textures over single-faced `IndexedFaceSets`. Each texture is related with a keyword, and the system looks for keywords in the object name; if it finds a texture with the same keyword of the object, a symbol is created. Figure 5 (left) presents an object called "Statue" built with nine box primitives, two spheres and three `IndexedFaceSets` (each one with million of points); it has 191kB and was inserted in the system with the keyword "statue". The corresponding symbol is shown right top, and right bottom its visualization from some distance. The symbol requires only 3kB.

The system was tested on a large virtual world depicting the historical quarter of the city of Recife (PE, Brazil).

Navigation was enhanced reducing by a factor of 4 the required time to explore it.

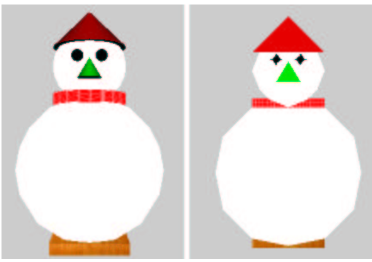

Figure 3: Original VRML object (left) and its LOD (right).

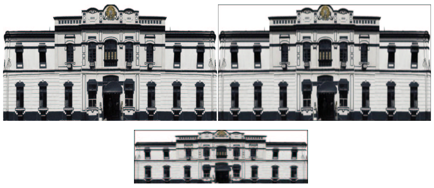

Figure 4: Original, blurred and sampled images.

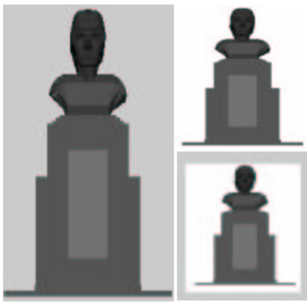

Figure 5: Example of symbolization operator.

The figure 6 exibits this historical quarter and the figure 7 exibits the result of generalization process in this virtual world.

5 CONCLUSIONS AND FUTURE WORKS

This work presented a transposition of ideas and tools from the realm of Cartographic Generalization to the managing of virtual reality worlds. A system for implementing this transposition was developed, and it is successful in performing its task. More operators are under development for extending the functionality of the system.

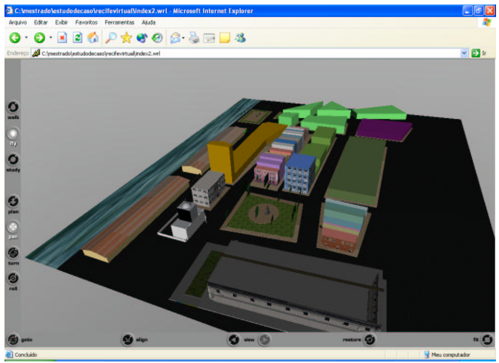

Figure 6: Historical quarter of the city of Recife

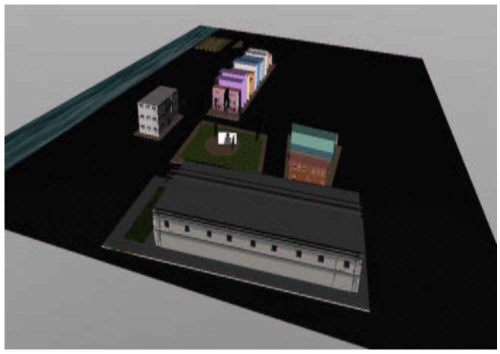

Figure 7: Result of generalization process in the historical quarter of the city of Recife

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