A Framework for Visualization of Geospatial Information in 3D Virtual City Environment for Disaster Risk Management

Asli Yilmaz [1], Sebnem Duzgun [2]

[1] Geodetic and Geographic Information Technologies,
Middle East Technical University, Ankara, Turkey
aslimail2me@gmail.com
[2] Mining Engineering, Middle East Technical University, Ankara, Turkey
duzgun@metu.edu.tr

Abstract. Visualization of geospatial information is a key issue since it is a bridge between this rich and high level information and its users to support decision making, management and operations. In recent years, new developments in technology provide new methods and platforms that enable innovative visualization of geospatial information. Among the possible platforms, 3D geospatial environments are increasingly preferred as they not only depict the real world but also convey additional information. This study, in the big picture, will cover theories from the disciplines of Cartography, Human Computer Interaction, Information Visualization and Cognitive Science which are considered to be most supportive and associative disciplines for finding solid and innovative geovisualization strategies. Considering the disciplines, Bertin's "theory of graphics" that defines visual variables for expressing information is set as a starting and connection point of the study. This study's aim is to create a framework for visualization of city objects and attributes that are critical in Disaster Risk Management in a 3D virtual city model. The framework is expected to be useful for designers, GIS vendors and researchers. More importantly, it is expected to help users make efficient and effective decisions.

Keywords: Geovisualization, Visual Variables, Disaster Risk Management, Decision Making,

1 Introduction

Virtual 3D city models are rapidly increasing with explicit semantics, topology, and thematic information (Döllner, 2009). They become essential computational tools as they allow 3D analysis, simulation, navigation, communication and management. (Döllner, 2009; Baig and Rahman, 2011). According to Petzold and Matthias (2011), 3D city models are generally more useful if they include additional data which can be analyzed with 3D representation of real world. Although 3D geospatial environments are increasingly used and many standards are created for them, they focus on technol-

ogy and 3D construction. According to Bleisch (2012), creation of 3D geospatial information is often very technology driven and misses a solid useful theory. Most research focusses on technology and process part, usefulness or cognitive outcomes are rarely evaluated (Bleisch, 2012). For many aspects involved in 3D geovisualization theory and design guidelines do not yet exist and suitable evaluation methods are needed (Slocum et al., 2001; Ellis and Dix, 2006).Efficiency and effectiveness or measuring task completion time and success /error rates are typically used as usability evaluation (Bleisch, 2012). User individual differences such as cognitive abilities, socio-demographic profiles, individual knowledge bases and understandings of the underlying study is not systematically examined considering the involved uncertainties for geovisualization design process (Slocum et al., 2001).

The framework for visualization of information can have roots from "Bertin's Variables" in "Semiology of Graphics". His theory related with visual variables is one of the most fundamental theories adopted by cartographers, cognitive scientists and researchers of Information Science. It is a flexible and expandable theory that all disciplines considered for this study can connect well. Bertin (1967/1983) is the first cartographer that set off fundamental visual variables for depicting spatial information. The variables he proposed are size, value (brightness), color, position (dimensions on the plane), orientation, texture and shape. Most researchers later manipulated Bertin's theory by adding or deleting variables and using them at different contexts. For example, Morrison (1974) included color saturation. MacEachren (1992) added three variables crispness, resolution and transparency. Other examples of variables studied are structure or pattern arrangement (Muehrcke and Muehrcke, 1992), abstract sound variables (Krygier, 2004) and focus (effect of fading, blurring or fuzziness) (MacEachren, 1992). However, including these extensions systematic evaluations in real geospatial environments with real users still lacks. Also, the original graphical variables are not identified according to 3D environments since at first they were proposed for visualization of 2D maps. Therefore, there is need for an exploration of variables in 3D environment, a taxonomy of applicable variables for 3D environment and validation of most effective, efficient and satisfactory possible usages with real users and real tasks to tackle uncertainties in 3D visualization. A visual taxonomy for geospatial visualization is aimed to be designed by understanding 3D design mechanisms and related uncertainties, which can offer a visual variable set for better presenting information in Disaster and Risk Management, which contains various information containing uncertainty like earthquake risk.

This study's aim is to create a framework for visualization of city objects and attributes that are critical in Disaster Risk Management in a 3D virtual city model. While doing this the study aims to consider the users' needs. It is expected to the framework will help users make efficient and effective decisions. Therefore, the methodology covers a deep user research in the beginning and the model will be designed according to user centered design process. The city objects and information to be visualized were decided by interviews with decision makers of Disaster and Risk Management who are the users of the study and supposed to deal with uncertainty. The users specified the city objects and attributes with uncertainties that should be visualized in the model.

The city objects proposed to the users for choice were the objects defined in the standards of City GML standards/ OGC.

2 Methodology

The study begins with defining user requirements (Figure 1). The users of the study are the decision makers of phases of Ex-Ante Strategies (Pre-disaster management). In the first step, in-depth interview method was used in order to define users according to profiles and roles. The second step has been completed by selecting city objects through evaluations of user requirements and additional literature review.

During the third step, which is in progress now, the objects' attributes will be visualized by different visual variables. Then, a visual taxonomy generated from different visual alternatives will be evaluated by User Experience Designers and Geographic Information System Experts. By the help of them various alternatives of visualization will be eliminated. In the fourth step by combining the city objects selected in the second step and visual taxonomy decided in the third step, three 3D city model alternatives will be designed and visualized. It can be clearly stated that the process between the first step and the fourth step is iterative till the user needs are clearly understood. Afterwards, in the fifth step, by making tests with users, most effective, efficient and satisfactory set of visualizations for 3D city model will be decided to be used in disaster management. The selected set will be chosen according to minimum time, effort and workload causing to the users to perceive the information by considering the uncertainty. Lastly, sixth step will consider generating a generic and solid framework that is appropriate to users of the study.

Fig 1. Research Methodology of the Study

3 Third Step: Creation of Visual Taxonomy

During creation of visual taxonomy, three dimensions will be considered. These are Measurement Scale (Measurement level of the data) (Nominal, ordinal, interval/ ratio), Level of detail (LoD levels specified by City GML standards) and Visual variables (size, color, texture etc...) The dimensions of the taxonomy is illustrated with an example and can be seen in Figure 2. According to this explanation, the attribute to be visualized will be defined according to its measurement scale, the level of detail it to be modeled and with which visual variable to be visualized. For example, type of building can be expressed as nominal. However, it can be visualized differently by using different visual variable and level of detail as seen in Figure 2.

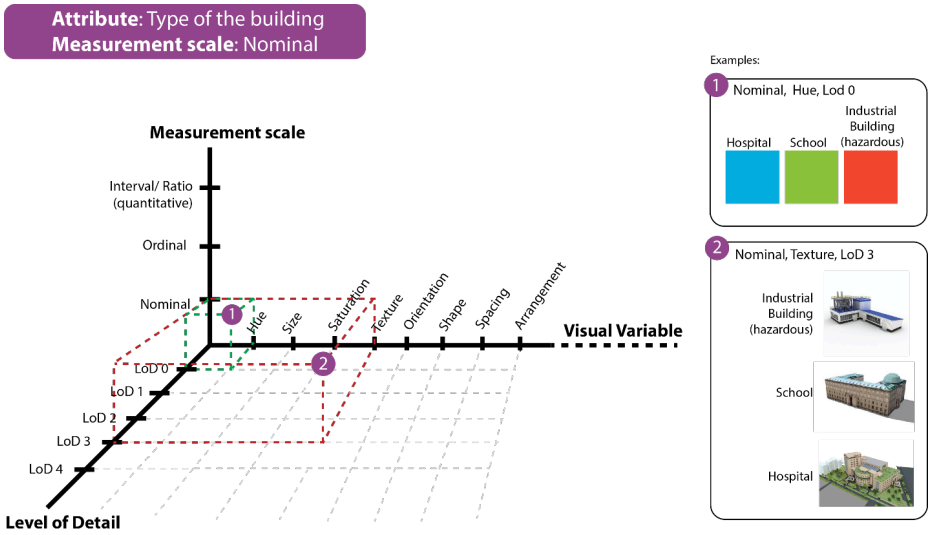

Fig 2. Three Axes of Visual Taxonomy

3.1 Adaptation of 2D Visual Variables to 3D Environment

Although many authors study how to convey information containing uncertainty effectively and efficiently with visual variables in 2D environment, few studies focus on their extended structure with design mechanisms in 3D environments. Actually perception of basic visual variables' in 2D Environment differs in many aspects when compared to their perception in 3D Environment. In 3D environment, global mechanisms can be created in a scene that lighting, shading, shadowing, exposure, background and environmental properties can be defined. Also, change in viewport effect the perception. Perspective views enable depth of field. Therefore, expression of visual variables are tightly linked with global and viewing design mechanisms. Moreover, as it can be seen in many 3D modelling programs (Unity, 3D Max, Rhinoceros, x3D) in 3D environment, any object is visualized by changing components of material and texture/map properties. A visual variable can be defined in more complex manner. For example color is defined as diffuse color, emissive color and specular color. Texture can be visualized by UVW mapping properties that are mathematical mapping techniques for coordinate mapping on an object.

As stated 2D static variables should be adapted for 3D Environment. By examining three well-known 3D Cad programs which are Autodesk 3Ds Max, Rhinoceros and Unity adaptation of visual variables is defined for the study. The 2D visual variables' equivalents were defined under the main headings *Material* and *Texture* for 3D environment.

4 Case Study

According to Hierarchical Task Analysis created after user interviews, Risk Assessment phase was the fundamental phase that all other phases were connected. Therefore, it can be stated as starting point of Disaster Risk Management. A case study is designed where Risk assessment of the buildings will be actualized by scoring the building according to criteria; accessibility during disaster, technical features of the building, distance to epicenter, importance in emergencies and number of residents. This step which is called prioritization is a part of Risk Assessment Phase. The scores are conducted according to these criteria during site visit by Disaster Risk Management Specialists. This step is done for buildings which can be used for other phases such as rehabilitation of public buildings (Mitigation), risk shifting from stakeholders to insurers (Risk Transfer), evacuation planning for buildings (Preparedness) and baseline for renewing city planning (Risk Avoidance).

The city model that is modeled in 3D environment is the representation of a district in Eskisehir, Turkey. Visual platform that is used for the study are Rhinoceros and Autodesk 3Ds Max. The visualization of the risk scores will be created on the same platforms. The model is prepared as 3 different levels of detail. LoD 0 model presents the foot print of the district. LoD 1 model presents the extrusion of the footprint model according to the height of the buildings. Buildings do not have roofs and texture. LoD 2 model presents the buildings and roads as textured. The buildings are not modeled in detail but have textures. The buildings have roof textures that are textured.

5 Future Work

The study is in progress. 5 further steps for future work can be stated as:

- Screenshots of visual alternatives for risk visualization according to the 3 axes will be prepared (Until now, some part of it has been prepared).
- Screenshots will be presented to 3 UX Designers and 3 GIS Experts and be evaluated. In the evaluation part, some of the screenshots will be eliminated. The elimination method will be suggested to the designers and experts as Analytical Hierarchy Process (AHP).
- The test procedure and alternatives to be presented to the users will be prepared.
- Test sessions will be actuated. The users to be participated to the test sessions will be held for 35-40 Disaster Risk Management Specialists which have active role in Risk Assessment Phase.
- The test sessions will be analyzed and visual taxonomy will be evaluated and redesigned.

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