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3D VISUALIZATION FOR URBAN ERTHQUAKE RISK

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Abstract

Visualization is the graphical presentation of information, with the goal of improving the viewer's understanding of the information contents. As today's world is getting richer in information, visualization of the information is important for effective communication and decision making. In this study, generation of a 3D city model in CAD environment and its use in a spatial decision support system for earthquake risk in an urban area is presented. As CAD products' quality is more enhanced than the other tools the 3D city model is generated in CAD environment. In CAD environment, a 2D building foot print vector layer is used. After extrude operations, real building textures are obtained by taking pictures from the study area. Texture mapping tools are used to cover extruded buildings with acquired building texture images. The 3D city model is used to visualize each building's earthquake risk level. The model also serves for querying and scenario analyses in a spatial decision support system.

1. Introduction

Natural disasters cause various losses such as life, structure, infrastructure, work and economical loses. Disaster risk could be reduced by using effective strategies. The visualization of the assessed risk is one of the essential tools for disaster managers, and the public.

As today's world is getting richer in information, visualization of the information is important for effective communication and decision making. The 3D visualization in Computer Aided Design (CAD) is powerful tool for conveying information to decision-making process in natural disaster risk assessment and management. Decision makers should be well introduced to the problem by effective visualization of information so that they could generate applicable strategies (Godschalk et al., 1998). A typical disaster risk reduction framework's steps are; Risk awareness, knowledge development, application of measures and early warning systems (ISDR, 2002). Effective visualization properties could play important roles in all fields of this framework. In this study, a 3D city model is developed and the earthquake risk is visualized on the developed model.

2. Overview to the 3D City Modeling

3D city models generally used by government agencies for urban planning, public safety studies such as fire propagation, commercial usages including phone, gas or electric companies etc. Most of these examples are interested in modeling buildings, terrain and traffic network in the city model. Models, used for visualization, could be grouped into three with respect to their data acquisition methods. These are photogrammetric, active sensors and hybrid sensors (Hu et al., 2003).

Photogrammetric methods are cost effective at large scale 3D urban models. Terrestrial, panoramic and aerial image methods are in this group of modeling. There are some example models that created from panoramic photos. An example could be the MIT campus study of Teller et al. (2001). As basic data source for photogrammetric methods is aerial images, they provide reliable footprint and roof height information for each building in the model area. Today 3D city model from aerial image studies generally focused on extracting accurate roof models from images, Lin and Nevatia’s model predefine L, T and I shaped roofs and assign most suitable roof shape to the examined building’s roof (Lin and Nevatia, 1998). Stereo aerial images could also useful tool for extracting 3D objects (Baillard and Maître, 1999). Lack of building façade information requires additional sensor data to be acquired for visual realism. Manual and semiautomatic methods give more mature results than fully automatic systems. Knowledge based and machine learning algorithms are another hot research area for the atomization of that kind of systems. Bellman and Shortis, (2002) and Nevatia and Huertas, (1998) are two example application of this kind. Both of them used knowledge and machine learning algorithms to improve the performance of the automatic building extraction.

Active sensor could be defined as; a detection device that emits energy capable of being detected by itself. Basically there are two kinds of active sensors used for city modeling. Ground based and airborne based. Ground based systems are ideal for vertical textures especially for historical structure façades (Frueh and Zakhor, 2001). However, they provide less accuracy for upper portions of tall buildings and these systems could not obtain roof and footprint data. Light detection and ranging (LIDAR) technology is also used for 3D city modeling studies. LIDAR technology constitutes great potential for the atomization of modeling issue.

Most city model applications use different data sources to obtain a model. This requires hybrid usage of different sensors. Each of these data sources and corresponding modeling technique have advantages and disadvantages (Ribarsky et al. 2002). Today 2D GIS data are often available in most cities. Many model applications use these data for their application (George, 2002 and Norbert and Anders, 2002) 2D CAD data provide accurate urban features and boundary data. Mainly boundaries are very usable data sources for image segmentation. Limitations for CAD systems could be listed as data management capabilities, spatial data management and spatial modeling. Main strengths of the CAD systems are clear and detailed graphical presentation controllability and edit capability of graphical features, Graphical presentation is important for the proposed purposes of the paper and CAD properties are used for the generation of the 3D city model and the visualization of the related data.

3. Study Area and Data Sets

For 3D city model application a pilot area was selected from Eskisehir metropolitan area in Turkey. This pilot model had been thought to undertake an overview function for how a complete 3D city model of the region would be look like? Using areas defined with legislative boundaries (quarter in this study) could be better than a solely physical area boundary definition to apply that kind of model.
Cumhuriye Quarter was chosen as pilot study area with beforehand enumerated reasons. It is a quarter in the central business district of the Eskisehir city with 4113 population according to the 2000 census. There are 434 buildings within the quarter.
Four main data sets were used in the study,

- Vector layers from Eskisehir Municipality,
  - Street layer of the city
  - Building layer of the Cumhuriye Quarter (pilot area)
- Building façade images collected by field survey
- Auxiliary data of various vulnerability indexes (socio-economic, structural, physical accessibility and total disaster vulnerability indexes) for the buildings.

To improve the realism of the 3D model in CAD environment, building façade images were used. These façade images were collected from the related buildings from the pilot area. The model of the digital camera used to collect façade images was Canon Powershot Pro1. Technical specifications of digital camera;8-Megapixel CCD for images up to 3264 x 2448, 28-200mm equivalent f/2.4-3.5 7x zoom, 15 - 1/4000 sec. shutter speed.
After creation of the 3D city model, the vulnerabilities of the structures, socio-economical condition and physical accessibilities are visualized by using model

4. Model creation phases

The created 3D city model forms the basis of simulating various disaster scenarios and their visualization. Advanced visualization improves decision maker’s perception level and this property constitutes the main worth of the CAD based 3D city model. The 3D city model provides a Virtual Reality (VR) environment, to create VR environments, first of all digital 3D scenes have to be constituted. For digital 3D city scenes creation 2D vector data (building foot prints and road) were used. Layers in CAD environment are constructed based on the number of story of the buildings.

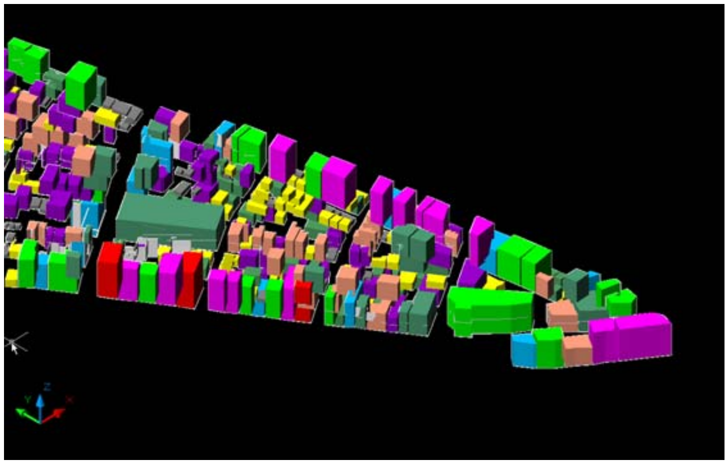

Figure 1. Solid CAD model of the study area, colours represent the floor number of buildings

The façade images, collected from the field by using a digital camera were used to map for the external surfaces of the 3D solid buildings. Different aperture values were used to gain homogeneous exposures of all images. Several difficulties are also faced during field data collection:

- Difficulty of taking photographs of some buildings which have official secrecy (i.e. police and military buildings),
- Dense and tall buildings in narrow roads, with perspective distortions on the façade images.

The collected images need to be corrected for geometric, atmospheric, radiometric and angular distortions. For this purpose post processing techniques were applied to remove these distortions.

Before mapping the field images to the building surfaces, to improve the image quality and remove the distortions, image rectification functions applied (Figure 2). Depending on the 3D city model generation aim, the accuracy level of the model varies. Because of the fact that our study did not have any photogrammetric goal, there was no photogrammetric network study for each façade image. Each image was manually rectified to be a façade image for 3D city model. After image rectification operation, four corner points of images were used for coordinate system transformation of the related façade image.

(a) (b)

Figure 2. Before (a) and after (b) rectification operations of an example façade image from study area.

Applied image rectification functions could be listed as; cropping, contrast enhancement, rotating and perspective adjustment.

Created 3D solid model (Figure 1) by using 2D footprints maintained from Eskisehir Municipality should be made ready to façade image mapping. Separate objects were created for four façades of each building to map each façade’s original images on it (Figure 3). Roads with river layer also superposed to the building layers to have a complete appearance of 3D city model. Created 3D drawing at CAD environment and processed façade images then transferred to another CAD environment where images could be map to the related façade.

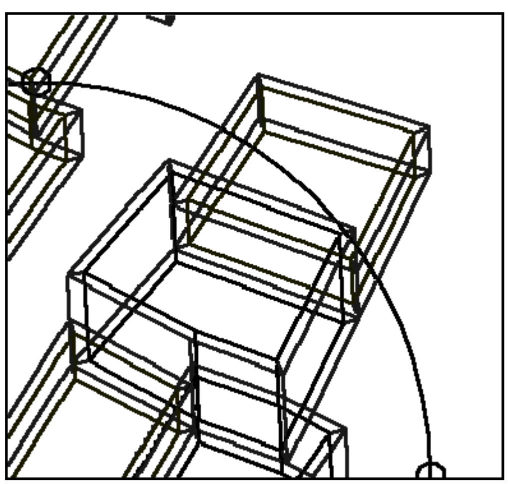

Figure 3. the objects created for mapping building façade

Visualization in the CAD Model

In order to enhance virtual reality of generated environment, some other complementary elements like river and road texturing and creation of sky over building model is also necessary. A simulation video produced with these captured scenes to simulate constituted 3D city model (Figure 4). Video was produced by using 4000 single image, captured on three different camera lines. Each single image was at 1600x1200 pixels resolution. The creation and visualization of the 3D model is an endless operation in CAD environment. Each chance has to be upgraded on the model to have a fully complete city model. Most time consuming and labor-intensive part of the 3D model generation was the creation of the virtual reality environments. There is no commercial software which has realistic buildings, with their true façade texture and fully automatic, modeling functions yet. On the other hand laser terrain scanning technology constitutes great potential for this atomization issue.

Figure 4. General view from the 3D city model

Disaster vulnerability indexes of the buildings are visualized by using index tables. Index table of each building could be seen with dropping building façade in the created video. When bypassing building, façade image is dropping and the index results are seen on the index table. Façade images are raised after passing near a building (Figure 5).

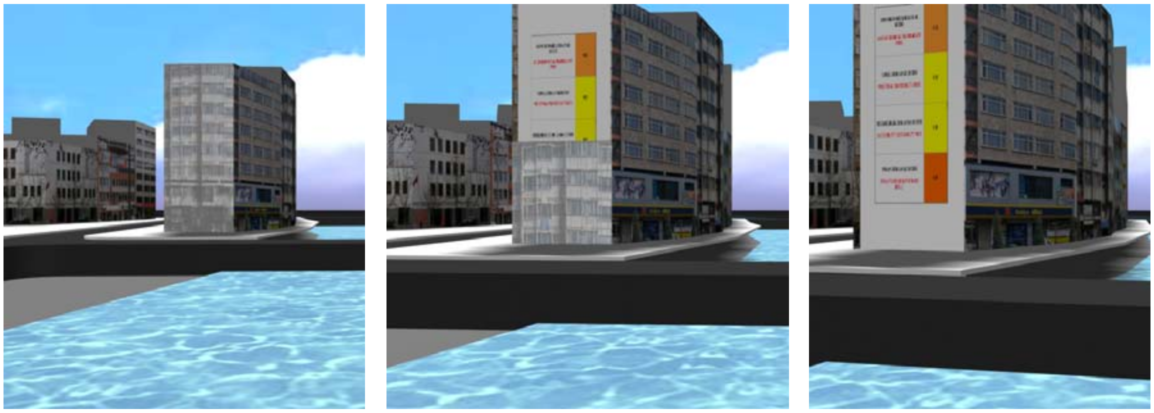

Figure 5. Visualization of various vulnerabilities in the 3D city model.

5. Conclusions and Future works

Main aim of the 3D city model was visualization of different (as total, socio-economic, structural and physical accessibility) disaster vulnerability indexes for each building in the study area. The CAD technology used for the model generation enables advanced visualization properties which improves decision maker's perception level.

Accurate roof modeling and terrain knowledge is the basic deficiencies of the generated model. To improve the realty level of the model integration of photogrametric and active sensor methods are plans of the authors.

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