IPT-EGVE Symposium (2007)
B. Fröhlich, R. Blach, and R. van Liere (Editors)

3-D Reconstitution and Virtual Reality of World Heritage Site in Danger: the Citadel of Bam

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Abstract

This paper presents research in progress on 3-D computer simulation and a virtual reality demonstration of a world heritage site that was destroyed in the earthquake (the citadel of Bam). In a comparative study with other examples of VR of cultural heritage, the approach of this research is introduced as analytic and comparative 3-D modelling (mostly as mesh or poly modelling) using diverse data resources such as 2-D maps, photos, etc. and VR demonstration of ten case studies as the result of first phase of the research.

Categories and Subject Descriptors (according to ACM CCS): I.3.5 [Computer graphics]: Computational Geometry and Object Modeling, I.3.7 Three-Dimensional Graphics and Realism.

1. Introduction

This paper presents the results of a research on the virtual reconstitution and VR demonstration of a world heritage in danger site, the Citadel of Bam [Kar2001] that was seriously damaged in an earthquake in December 2003. The target of the research is to enable users to interact with the computer simulated spaces and walk virtually inside the buildings displayed on screen or by stereoscopic imaging. This might be the only chance for them to see and feel the heritage of Bam that was destroyed in the earthquake. The VR reconstitution digitally and permanently preserves the heritage of this site and can be used as a document for physical restoration as well.

The following section describes the process of 3D reconstitution that involved the creation of 3-D models from 2-D maps and other complementary resources. After that, the VR preparation process is presented. The paper concludes with current achievements and future prospects.

2. Process of 3D reconstitution

Examples of virtual heritage include reconstitution of the Great Buddha [MON*2000] which uses geometric modelling (scanning, merging and alignment of the target object) and photometric and environmental modelling for rendering and demonstration. The Parthenon virtual reality [STY*2003] was produced using laser scanning and photogrammetry for modelling. Another example is the virtual reality of the city of Pompei [JV2005] that created 3-D models of the target buildings from available documents. In a comparison of cases introduced above and citadel of Bam, our target buildings are mostly destroyed. Furthermore 3-D simulation is necessary for both the interior and exterior spaces of the buildings which were made from mud brick with traditional curves, arches, and other complicated shapes. The site is huge (about 200,000 m²) and comprises several districts. There are few detailed images of the buildings proper for photo 3-D modelling.

Therefore, photogrammetry or laser scanning seems not to be effective for making a computer simulation of this site. For our Bam VR, the 3D models were created using the 3ds Max tool [3ds Max] from 2-D maps (plan, section, etc.) surveyed before the earthquake. These maps had errors and superimposing incompatibilities. The photos taken at the site before the earthquake were gathered from diverse resources (from organizational archives to personal albums of tourists), and after classification and annotation, they were used to disambiguate the maps. Aerial photos, three-dimensional cartography (IFCA project of Pr. C. Adle from CNRS in France), movies, texts, sketches of architects, etc., were used to complete the basic resources for 3-D modelling (These data were provided mostly by ICHTO and NCC from Iran). The task needed continuous survey in the site and control of the 3-D models and consequently involved different teams of 3-D modellers (a Japanese team from Waseda University, an Iranian team from the University of Tehran, a French team from EVCAU, ENSAPVS) with support from the Iranian Cultural Heritage and Tourism Organization and the Bam recovery office.

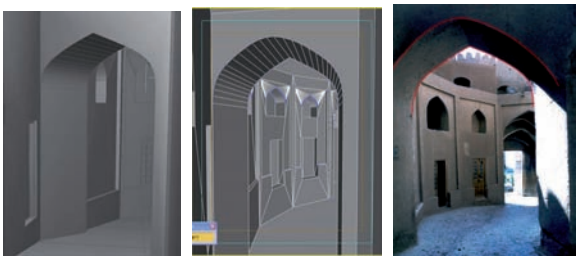
Although this research used state-of-the-art 3-D modelling methods, the virtual reconstitution process is particular to the citadel of Bam. We selected a suitable method for modelling mud brick buildings with soft edges and curved shapes from the modelling tools' large options such as mesh, poly, patch or NURBS modelling [Fle 1999]. Furthermore, modelling the features of the traditional architecture required a specific drawing process to be followed by the modellers. A technical guideline with these instructions was written by computer graphics experts and

architects of our team for modellers and their output 3-D models were controlled precisely by the team of evaluators. Some items of the guideline are introduced as below:

Use specific techniques for modelling different elements of the building. For example, use of mesh for interior vaults (and optimize the size of meshes to avoid a heavy file) and poly modelling for the surfaces of roofs.

Use the layer manager option and a layer naming strategy in order to group together objects of 3-D model with similar attributes and locate the group under a specified layer. The name of each layer indicates the name of the building, the type of data, and the type of component.

Start modeling from 2-D maps, then adjust the heights and free shapes of roofs from the 3-D cartography map and modify facades and missing parts with photos and sketches. Specifically for photos, use the "Camera Match" utility of the modeling tool so that the common characteristics between the photograph and the CG model will correspond, to make comparisons and modification (as shown below).



Figures 1, 2 and 3: *Modelling from maps (left) and modification of the arches from photos (middle and right)*

3. VR preparation process

The rigorous process involving the collaboration of CG experts and architects resulted in ten major buildings inside the citadel of Bam being modelled as 3ds Max files. All the 3-D models were combined into a unified environment. The layer management method ensured there was no error due to similarities of names during the process of merging the files together. The basic general map to superimpose the 3-D model was a rough topographic map of the citadel of Bam after the earthquake (Provided by NCC), which was imported to the 3ds Max tool and mapped with a black and white aerial photo. The 3-D models were then positioned by using the geographical features (longitude and latitude) of the 3-D cartography map of each building. The whole file was then exported to the Omega Space tool.

Omega Space is a state-of-the-art VR space construction and experience tool which offers real-time rendering in a PC environment [Omega Space], and its interactions matched our needs. The simulated 3-D model was output in VRML form with coordinate information, and read into Omega Space. The process is specified in Figure 4. We arranged the light arbitrarily, and set up two or more virtual cameras for each building. Walk-throughs would able to be done in the VR space by switching between cameras with a joystick. Moreover, a collision detector was set up to prevent the operator from entering the restored CG model while the user is walking through virtual spaces.

4. Conclusion

The first trial demo of the VR of ten buildings of the citadel of Bam (Figure 5) was given at the site of Bam in September 2006. The contrast between the demolished buildings and the virtual restorations had a deep influence on the visitors who took part in the demo. We envision extending the VR to other parts of the site specially to important types of buildings and the governor district.

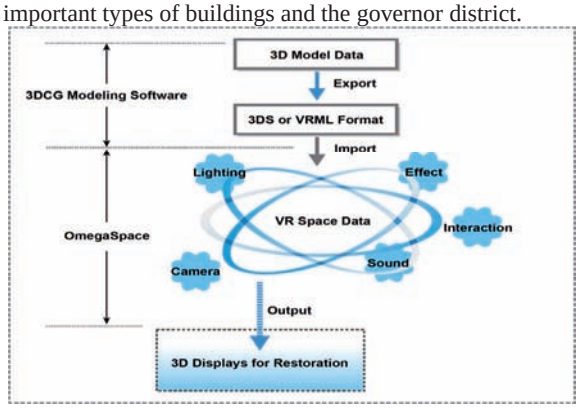


Figure 4: *Workflow of making VR using Omega Space.*

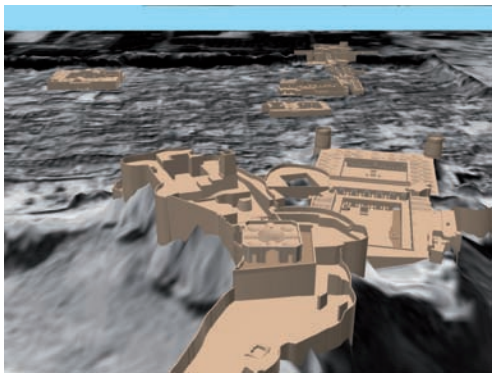


Figure 5: *VR of the citadel of Bam: 10 case studies*

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[Omega Space] Omega Space tool of Solidary http://www.solidray.co.jp/product/omega/index.html

[3ds Max] 3ds Max tool of Autodesk www.autodesk.com/3dsmax