

Integration of landscape and city modeling : The pre-hispanic site Xochicalco

Armin Gruen, Xinhua Wang
Institute of Geodesy and Photogrammetry
ETH Zurich

Commission V, WG V/6

KEY WORDS: Digital Terrain Model, CyberCity Modeler, Visualization

ABSTRACT:

This paper describes how CyberCity Modeler is used in order to extract both the terrain and the man-made remains of a pre-hispanic site in Central Mexico, a task for which it was not intended originally. We take an oriented aerial stereomodel and measure the point clouds of all architectural structures and the Digital Terrain Model points in manual mode. The structuring of the objects is then performed automatically. This procedure ensures both high reliability and completeness of the models and a very fast production cycle.

We will also address the integration of the different kind of data (vector and raster) and the use of such a hybrid 3D model for the purpose of visualization.

Such computer-based photorealistic and geometrically precise 3D model constitutes a new and interesting tool for the archaeologist for analysis and representation.

1. INTRODUCTION

Integrated models that combine both landscape and man-made objects are required in many applications. While digital terrain modeling with photogrammetric means has a long tradition and efficient approaches are available, the truly 3D modeling of man-made structures is of fairly recent nature and still an important research issue. Both types of models may be extracted from imagery together in a joint process or may become available separately.

According to Hirth, 2000 the pre-hispanic Xochicalco is unique among large archaeological sites explored to date in Central Mexico. Nowhere has a larger part of an urban center been preserved in better shape. This provides for optimal conditions for conducting archaeological projects using surface remains. Therefore surface mapping is very important here, because it includes a large body of information on public and domestic architecture. The analysis of such a mapping product, coupled with the recovery of in situ artifacts, provides an opportunity for intensive studies of community-level social and economic patterns. The related analog map was produced with conventional analog photogrammetric means in 1978 from 1:8000 aerial metric photography (Hirth, 2000, p. 50ff.).

In 1997 another photogrammetric flight was conducted over the site, producing colour images at scale 1:3000. We acquired three of these images from Hansa Luftbild GmbH, Münster, Germany with the goal to produce a 3D model for computer visualization and to test the suitability of CyberCity Modeler for this kind of work.

CyberCity Modeler (CC-Modeler) is a semi-automated approach for object extraction and modeling. It has been developed in order to generate 3D city models efficiently. In its original form it fits planar faces to measured and widely unstructured clouds of points which describe the key features of the objects of interest (Gruen, Wang, 1998).

Since CC-Modeler is a generic modeler it is not restricted to the modeling of buildings, but can handle many other kinds of objects as well. This paper shows how CC-Modeler can be used

to measure and model a fairly large archaeological site like the pre-hispanic structures of Xochicalco with minimal effort.

2. CYBERCITY MODELER

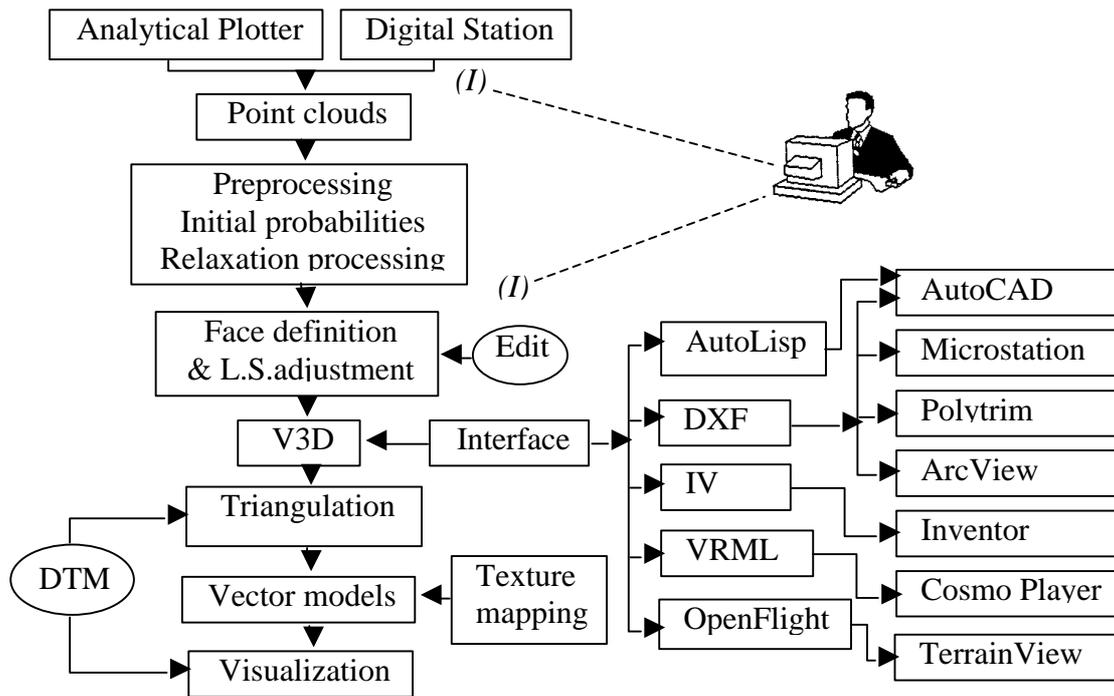
The work-and dataflow of CC-Modeler is shown in Figure 1. Within the CC-Modeler concept we measure the point clouds of relevant building features like ridge and eaves points in stereomode on an Analytical Plotter or a Digital Station. The use of the stereomode is crucial because very often the image content is difficult to interpret without 3D perception. When fitting a surface model to the point clouds each cloud, defining one building, is treated individually. In case of very complex building structures these must be subdivided into several point clouds, or computational units.

Each computational unit is passed through the process of probabilistic relaxation, which determines the assignment of points to object planes. Once this is achieved all planar faces are simultaneously geometrically fitted by a joint least squares adjustment.

The resulting object is represented by an internal data structure V3D, which has interfaces to all major commercial data formats. The Digital Terrain Model is either measured from the photogrammetric model or imported from external sources. The image texture is projected onto the roofs, the terrain and, if required, onto the facades of the buildings. While the projected roof and terrain texture is generated automatically the façade texture generation requires some manual intervention. The image raster data can also be integrated into the datastructure.

We have developed our own visualization software. For larger datasets and real-time visualization requirements however it is advisable to apply high-end commercial software.

In the meantime many extensions to CC-Modeler have been developed and implemented, which increase the functionality of the system considerably (Gruen, Wang, 2001).



(I)---Interactive functions

Figure 1: Workflow of CyberCity Modeler



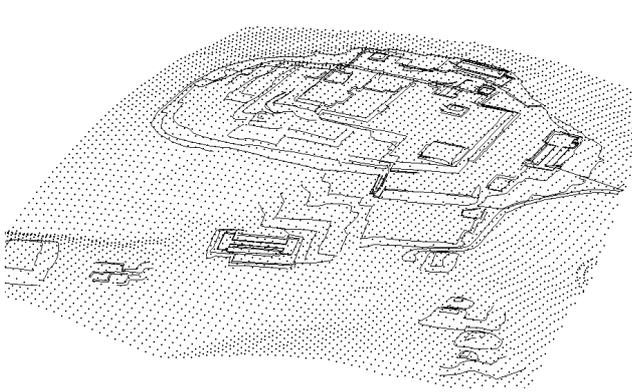
Figure 2: Central portion of an aerial image of the pre-hispanic site Xochicalco, original image scale 1:3 000

3. DATA AND 3D MODEL GENERATION

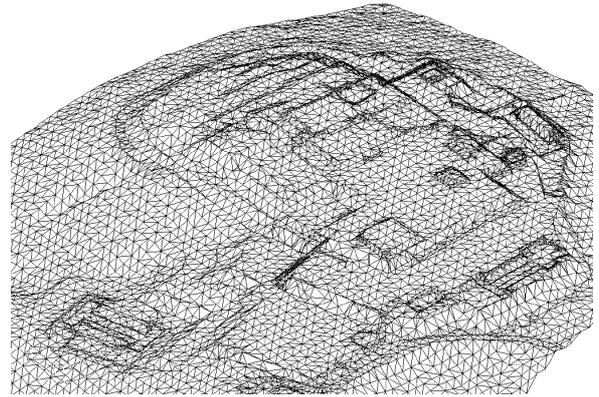
We used a pair of aerial colour images, taken over the site in January 1997 at an image scale of 1:3000 and with a camera constant of 153 mm. The images were scanned on the Vexcel UltraScan 5000 with a pixel size of 20 micron.

The measurements of the DTM and the point clouds of the structures were done on the Analytical Plotter AC-3. The

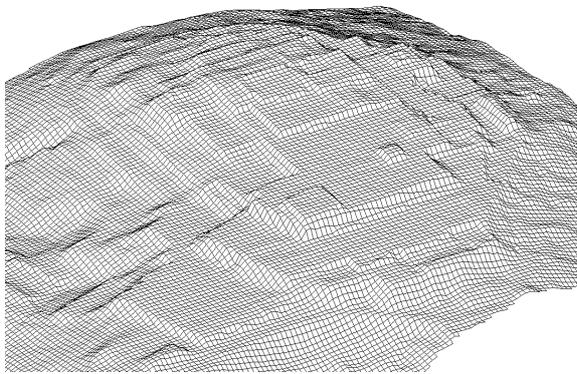
orientation of the model was performed with a minimal number of fictitious ground control points, since we did not have any real points available. The three height GCPs were chosen such that the model was leveled in good approximation. Since the model has no realistic scale (the only information about scale comes from image scale) any scale-related values are thus only given in image space. The DTM was measured in profile mode with a profile distance of



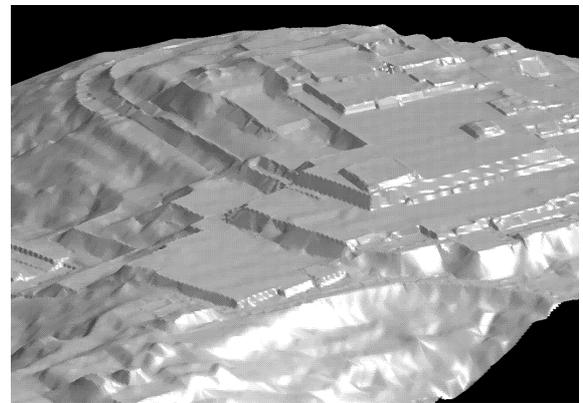
(a)



(b)



(c)



(d)

Figure 3: 2.5D DTM of Xochicalco

(a) Primary points, measured in profile mode plus breaklines (CC-Edit), (b) TIN structure (CC-Edit), (c) Wireframe, derived from (a) through (b) (DTMZ), (d) Shaded model (Microstation)

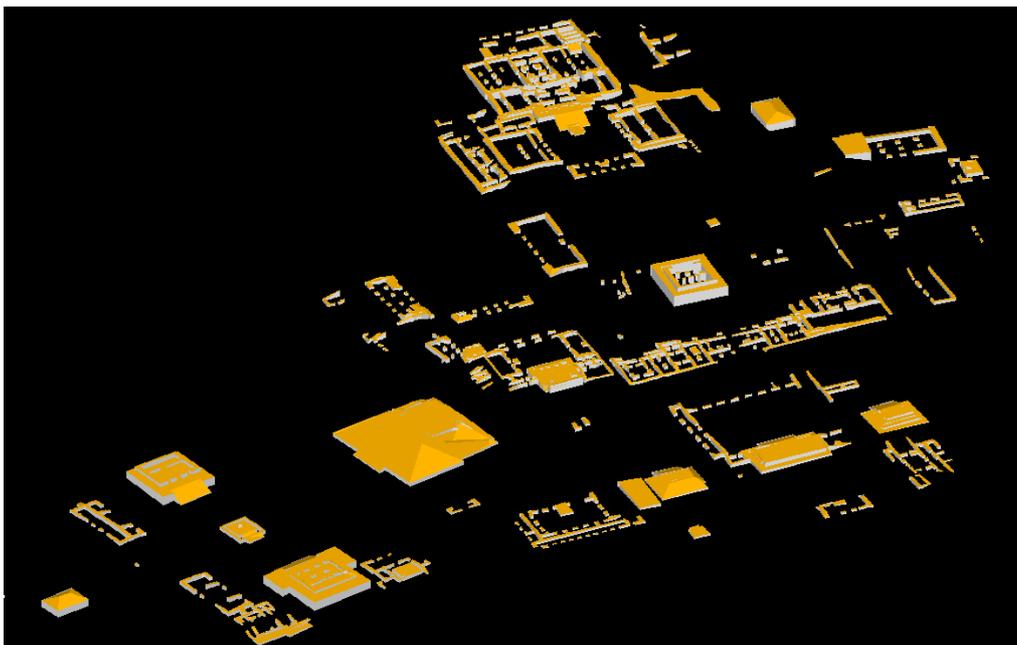


Figure 4: 3D model of the man-made structures (AutoCAD)

1.56 mm and with additional breaklines. In this way a total of 9739 DTM points was produced. This primary DTM was converted into a regular 0.234 mm grid raster with 8430 x 7830 points, using our own finite element-based interpolation software DTMZ. The object size of the model area is about 390 x 360 m². Figure 3 shows different forms of the DTM (primary data, TIN structure, wireframe and shaded model).

The man-made structures were extracted in point cloud mode, considering the specifications of CCM (Gruen, Wang, 1998). A total of 735 objects was measured and modeled without any problems and postediting efforts. Figure 4 shows the man-made structures as shaded model.

The texture mapping onto the roofs and the terrain is a fully automated process and can be done directly from the aerial images. Since the ruins of the project site do not have a conventional roof we also did not map any texture there. CC-Modeler has also the option to map the terrain texture via orthoimage. We followed this mode and produced a digital colour orthoimage with Virtuozo at 15.6 micron resolution, generating a file of 192 MB for the raw image.

The total amount of time spent on the generation of this photo-textured 3D model was about 5 working days, which demonstrates the efficiency of the procedures involved.

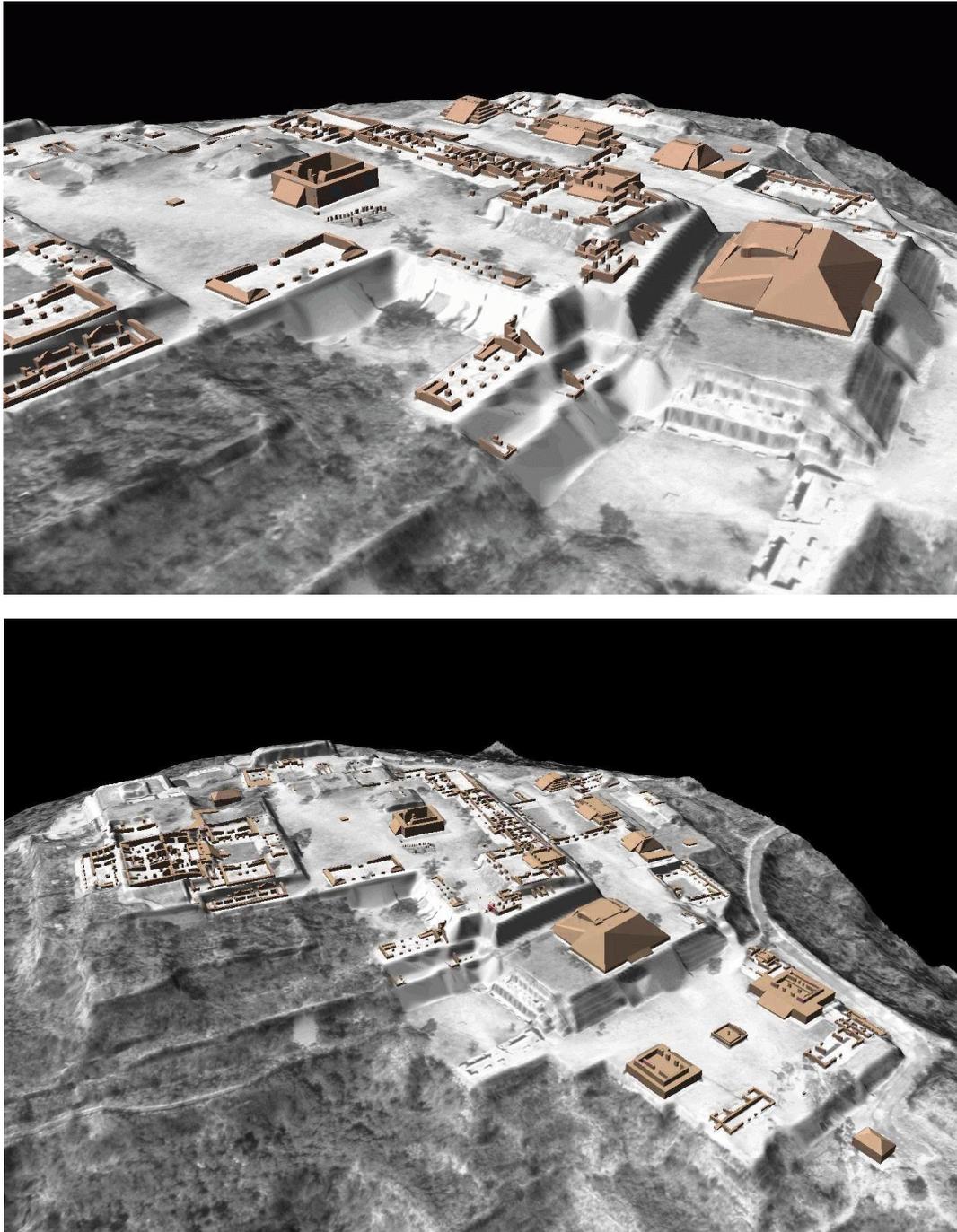


Figure 5: Two different views onto the 3D model of Xochicalco with photo-textured DTM (0.47 m texture pixelsize), VirtualGIS

4. VISUALIZATION

The visualization of the produced 3D model is very often a key element in the production chain. For the external world it is actually the first and often the only accessible and reasonable interface and possible contact to the 3D model. Very often the visualization remains even the only product of interest.

Visualization tools and software are available in manifold forms. In http://www.tec.army.mil/TD/tvd/survey/survey_toc.html for example we can access a list of about 550 software packages just for terrain visualization. Many more packages are probably lingering in various research labs. For the uninitiated user it is very difficult to select a program of choice and it needs a lot of testing and practical work with different kind of datasets before a critical assessment and acquisition decision can be made. Although the conceptual aspects of computer graphics algorithms are quite straightforward, it is always the implementation and the quality of the key components of the computer platform which define the performance. When analysing visualization software a major consideration is whether real-time performance is required or not. The fascination of real-time visualization is intriguing enough so that most users, once they have been exposed to it, will not want to do without it. Also, for many analysis applications real-time performance is just a must for the sake of economy and efficiency of operation.

Actually one can classify visualization software even on the basis of its real-time performance, given a certain computer configuration. In this context one can distinguish high-end, middle class and low-end systems (e.g. Skyline, IMAGINE VirtualGIS and Cosmo Player, in this order). While low-end software is increasingly available as freeware over the Internet, the other levels of quality can only be reached by paying, in parts dearly, for the product.

There are many more quality criteria, which can be applied, but since most of these are to be weighted differently according to the varying user requests we will not dig into this issue any further here.

Observing that computer power and graphics board performance is increasing dramatically over the last years one can nowadays expect even from laptops a rendering performance which was unheard of only 2-3 years ago. High-end performance of photo-textured 3D models can be obtained on laptops if the software supports that. One critical parameter here is the Level-of-Detail (LoD) property. LoD capability ensures that at each and every frame of an image sequence only the foreground portion of the 3D model is represented at highest resolution. Other zones of model depth are represented at lower resolution. This reduces the amount of computations substantially, an advantage which becomes the more prominent the bigger the model is. This LoD property applies both to vector and image raster data (Karner, *et al.*, 2001). The interested user should also pay attention to the fact whether the different resolution layers can be produced effortlessly by himself or whether a major economic effort is needed.

Since our 3D model of Xochicalco is of rather small size with 2.5 MB vector and 192 MB image raster data at full resolution, a software like Imagine VirtualGIS does a reasonably good job and the still views on the model shown in this paper are produced with this package. We have many datasets in other projects (Gruen *et al.*, 2002, Gruen, Murai, 2002) where VirtualGIS is not sufficient any more and a package like Skyline must be employed.

IMAGINE VirtualGIS uses OpenGL as the graphic language. This allows the user to use hardware accelerators for geometry and texture rendering and allows the software to run on UNIX workstations and on PCs. Figure 5 shows two views onto the 3D model with about 0.47 m texture pixel size on the DTM, produced with VirtualGIS. In Figures 3,4,5 we have mentioned the visualization packages used.

5. CONCLUSIONS

We have shown that CyberCity Modeler, an approach designed originally for the generation of 3D city models, can also be used in order to reconstruct and model archaeological remains. With the example of the large pre-hispanic site Xochicalco, Central Mexico we have demonstrated how a hybrid 3D model, consisting of vector data in form of a DTM and man-made structures and image raster data can be generated efficiently. The flexibility of CyberCity Modeler allows us to translate its internal data structure V3D in virtually any of the current commercial data formats so that we can make use of a wide array of visualization software. Real-time visualization of very large datasets (in the Gigabytes) has so far always been a serious bottleneck. However, we see currently solutions coming up which give us a tremendous performance even on laptop platforms.

This will open the realm of photorealistic 3D models to a much larger user community and will also intensify the need for efficient 3D model generation.

References

- Gruen, A., Wang, X., 1998: CC-Modeler: A topology generator for 3-D city models. *ISPRS Journal of Photogrammetry & Remote Sensing*, Vol.53, No.5, October, pp.286-295.
 - Gruen, A., Wang, X., 2001: News from CyberCity-Modeler. In Gruen, Baltsavias, Van Gool (eds.): *Automated Extraction of Man-Made Objects from Aerial and Space Images (III)*, A.A.Balkema Publishers, Proceedings of the Monte Verita Workshop, 10-15 June 2001, Ascona, pp. 93-101
 - Gruen, A., Sauerbier, M., Lambers, K., 2002: Visualization and GIS-based analysis of the Nasca geoglyphs. Paper submitted to the CAA 2002 Conference "Computer Applications and Quantitative Methods in Archaeology", 2-6 April, Heraklion, Crete
 - Gruen, A., Murai, Sh., 2002: Very high resolution modeling and visualization of Mt. Everest. Manuscript submitted to the *ISPRS Journal of Photogrammetry and Remote Sensing*.
 - Hirth, K., 2000: *Archaeological Research at Xochicalco*. Vol.1 and 2, The University of Utah Press, Salt Lake City
 - Karner, K., Bauer, J., Klaus, A., Leberl, F., Grabner, M., 2001: *Virtual Habitat: Models of the Urban Outdoors*. In Gruen, Baltsavias, Van Gool (eds.): *Automated Extraction of Man-Made Objects from Aerial and Space Images (III)*, A.A.Balkema Publishers, Proceedings of Monte Verita Workshop, 10-15 June 2001, Ascona, pp.393-402
- www.tec.army.mil/TD/tvd/survey/survey_toc.html