Virtualizing Archaeological Sites

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Abstract. More and more archaeological sites are being reconstructed in virtual reality. The problem remains the huge effort that has to be made to obtain realistic models. Besides on-site measurements, much time is often spend in manually rebuilding the whole site with a CAD package or a 3D modeling tool. This limits the tractable complexity. In this paper an image based automatic 3D surface acquisition system is used to "virtualize" archaeological sites. The Roman site of Sagalassos (south-west Turkey) is used as a test case to illustrate the potential of this new approach. Besides the construction of a virtual site consisting of different level of details, some more applications to archaeology and conservation of heritage sites are presented.

1 Introduction

Virtual reality is a technology that offers promising perspectives for archaeologists. It can help in many ways. New insights can be gained by immersion in ancient worlds, unaccessible sites can be made available to a global public, courses can be given "on-site" and different periods or building phases can coexist.

One of the main problems is however the generation of these virtual worlds. They require a huge amount of on-site measurements. In addition the whole site has to be reproduced manually with a CAD- or 3D modeling system. This requires a lot of time. In addition it is difficult to model complex shapes and to take all the details into account. Obtaining realistic surface texture is also a critical issue. As a result walls are often approximated by planar surfaces, stones often all get the same texture, statues are only crudely modeled, small details are left out, etc.

An alternative approach consists of using images of the site. Some software tools exist, but require a lot of human interaction [6] or preliminary models [2]. We have developed a system which can automatically reconstruct textured 3D models from image sequences of a site without prior knowlegde [8, 7, 4]. The advantage is that the reconstruction is much closer to reality, hence *virtualized* reality [3]. This technique offers a great deal of flexibility since it can work with a simple video- or photo camera. Additionally, zoom and focus can be varied freely during the acquisition [9].

All the examples in this contribution were taken at the archeological site of Sagalassos in south-west Turkey. The images were obtained with a consumer photocamera (digitized on photoCD) and with a consumer digital video camera.

2 Virtualizing scenes from images

The 3D surface acquisition technique that we have developed [8, 7, 4] can readily be applied to archaeological sites. The on-site acquisition procedure consists of recording

Figure 1: Image sequence which was used to build a 3D model of the corner of the Roman baths

an image sequence of the scene that one desires to *virtualize*. To allow the algorithms to yield good results viewpoint changes between consecutive images should not exceed 5 to 10 degrees. An example of such a sequence is given in Figure 1.

The further processing is fully automatic. The first step consists of calibrating the image sequence (i.e. obtaining relative position and orientation of the camera up to scale for the different viewpoints). This is done based on features which are tracked over consecutive images. The next part is the computation of the surface geometry itself. For every pixel in an image the corresponding points in other images are searched through crosscorrelation and an optimal solution is found through dynamic programming. Once corresponding points are known the actual surface is reconstructed in 3D through triangulation. The images can be used as texture maps. The result for the image sequence under consideration can be seen in Figure 2. An important advantage is that details like missing stones, not perfectly planar walls or symmetric structures are preserved. In addition the surface texture is directly extracted from the images. This does not only result in a much higher degree of realism, but is also important for the authenticity of the reconstruction. Therefore the reconstructions obtained with this system can also be used as a scale model on which measurements can be carried out or as a tool for planning restaurations.

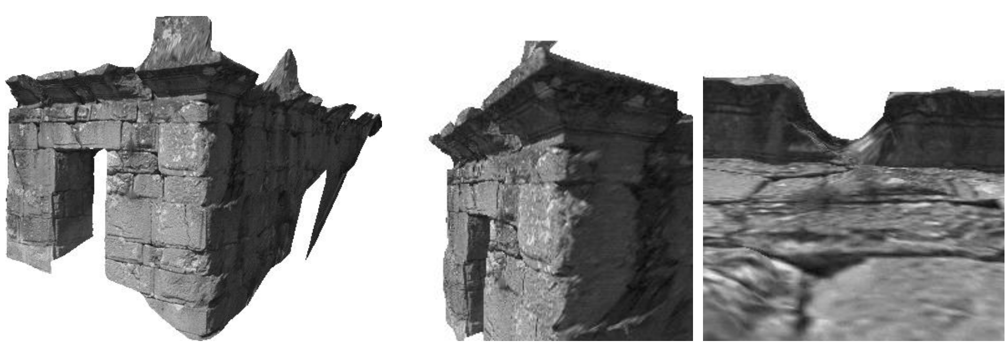

Figure 2: Virtualized corner of the Roman baths, on the right some details are shown

3 Virtualizing a whole site

A first approach to obtain a virtual reality model for a whole site consists of taking a few overview photographs from the distance. Since our technique is independent of scale this yields an overview model of the whole site. The only difference is the distance needed between two camera poses. An example of the results obtained for Sagalassos are shown in Figure 3. The model was created 9 images taken from a hillside near the excavation site. Note that it is straightforward to extract a digital terrain map or orthophotos from the global reconstruction of the site.

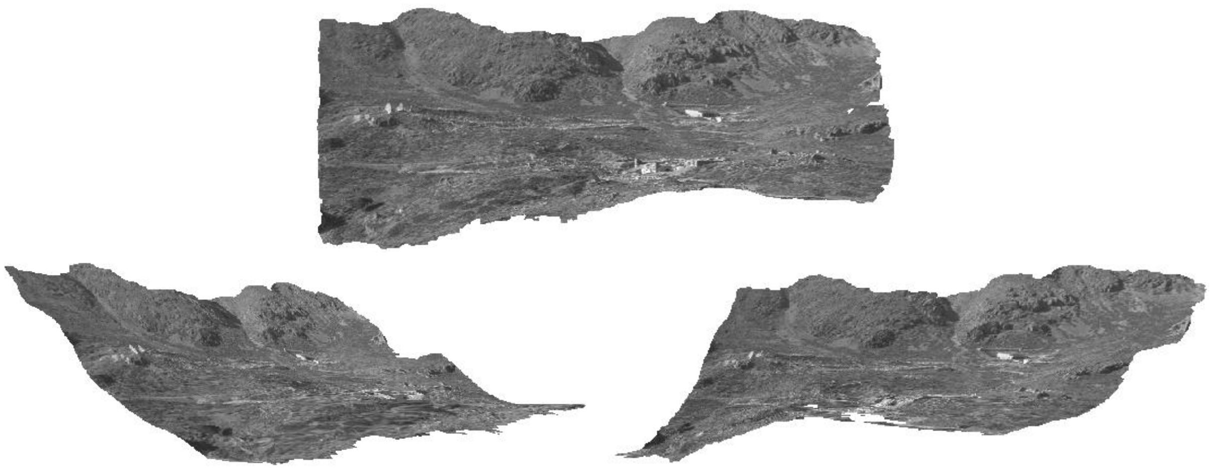

Figure 3: Overview model of Sagalassos

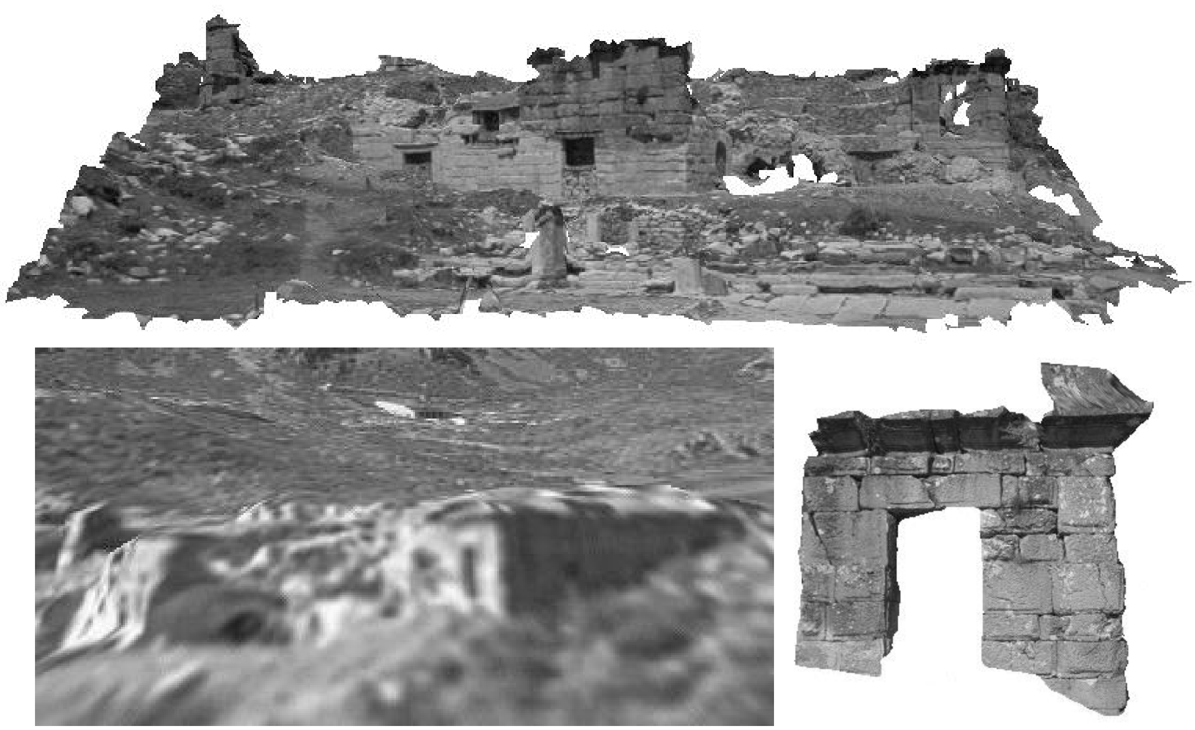

Figure 4: Models of the Roman baths at different scales: complete baths (top), zoom onto the baths in the overview model of Figure 3 (bottom left), detailed right corner of the baths (bottom right)

3.1 Integration of reconstructions at different scales

The problem is that this kind of overview model is too coarse to be used for realistic walk-throughs around the site or for looking at specific monuments. Therefore it is necessary to integrate more detailed models into this overview model. This can be done by taking additional image sequences for all the interesting areas on the site. These are used to generate reconstructions of the site at different scales, going from a global reconstruction of the whole site to a detailed reconstruction for every monument.

These reconstructions thus naturally fill in the different levels of details which should be provided for optimal rendering. In Figure 4 reconstructions of the Roman baths are given for three different levels of details (site overview, complete Roman bath house and detail of right corner).

3.2 Combination with other models

An interesting possibility is the combination of these models with other type of models. In the case of Sagalassos some building hypothesis were translated to CAD models [5]. These were integrated with our models. The result can be seen in Figure 5. Also other models obtained with different 3D acquisition techniques could easily be integrated.

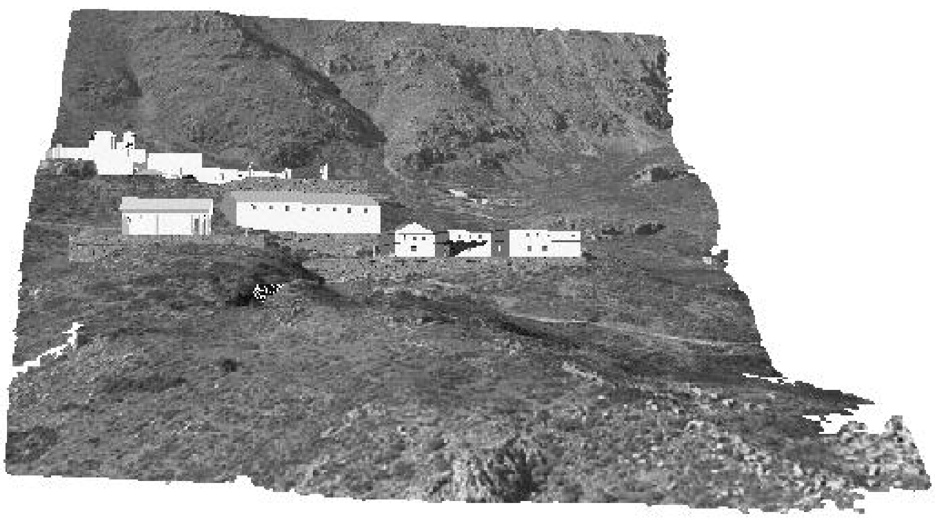

Figure 5: Virtualized landscape of Sagalassos combined with CAD-models of reconstructed monuments

4 Other applications

Since these reconstructions are almost completely automatic and the on-site acquisition time is very short, several new applications come to mind. In this section a few possibilities are illustrated.

4.1 3D Stratigraphy

Archaeology is one of the sciences were annotations and precize documentation are most important because evidence is destroyed during work. An important aspect of this is the stratigraphy. This reflects the different layers of soil that corresponds to different time periods in an excavated sector. Due to practical limitations this stratigraphy is often only recorded for some slices, not for the whole sector.

Our technique allows a more optimal approach. For every layer a complete 3D model of the excavated sector can be generated. Since this only involves taking a series of pictures this does not slow down the progress of the archaeological work. In addition it is possible to model separately artifacts which are found in these layers and to include the models in the final 3D stratigraphy.

This concept is illustrated in Figure 6. The excavations of an ancient Roman villa at Sagalassos were recorded with our technique. In the figure a view of the 3D model of the excavation is provided for two different layers.

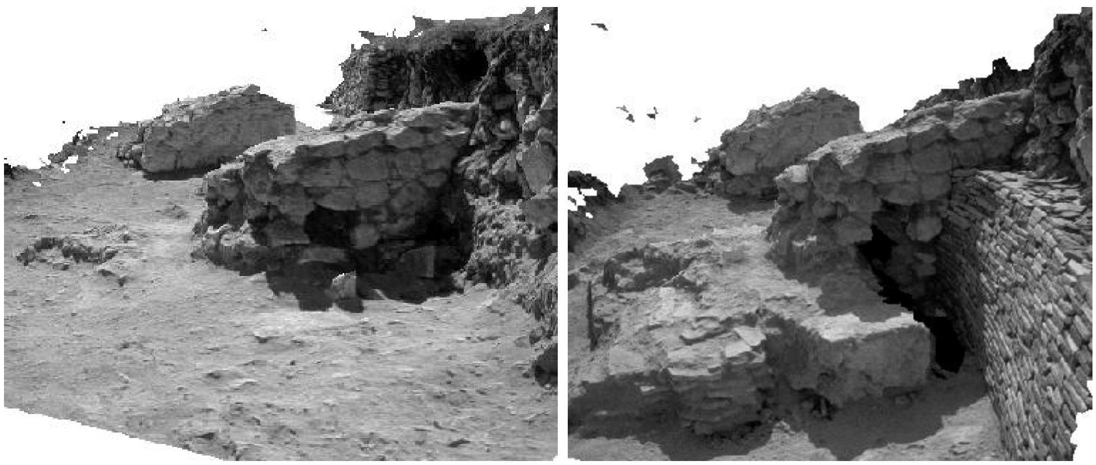

Figure 6: 3D stratigraphy, the excavation of a Roman villa at two different moments.

4.2 Generating and testing building hypothesis

The technique proposed in this paper also has a lot to offer for generating and testing building hypothesis. Due to the ease of acquisition and the obtained level of detail, one could reconstruct every building block separately. The different construction hypothesis can then interactively be verified on a virtual building site. Some testing could even be automated. The matching of the two parts of Figure 7 for example could be verified through a standard registration algorithm [1]. An automatic procedure can be important when dozens of broken parts have to be matched against each other.

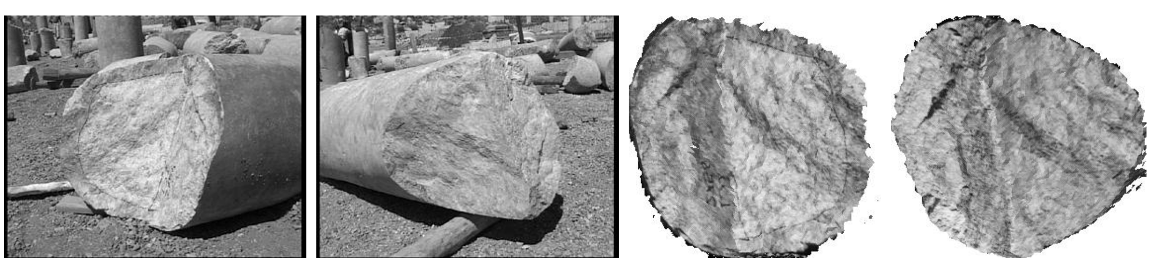

Figure 7: Two images of parts of broken pillars (left) and two orthographic views of the matching surfaces generated from the 3D models (right)

5 Conclusion

In this paper the possibilities of automatic 3D surface acquisition from image sequences for building virtual models of archaeological sites was demonstrated. The advantages are numerous: the on-site acquisition time is restricted, the construction of the models is automatic and the generated models are realistic. The technique allows some more promising applications like 3D stratigraphy and the (automatic) generation and testing of building hypothesis.

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