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# Maya Sun Simulation of Bosnian Gravestone Virtual Model

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**Abstract**

*Bosnia and Herzegovina is very rich with cultural heritage sites. Perhaps the most famous of these are the stecaks; the monumental gravestones of Bosnian Heretic Christians. The orientation of the stećaks was important to the ancient Bosnians, Unfortunately, their orientation towards the sun has been changed when they were moved from their original locations to more secure sites at museums. This is particularly true of the stećak from Donje Zgosce, one of the most beautiful stećaks in B&H. Using high-fidelity graphics techniques we have created a detailed virtual reconstruction of this stećak and produced a sun simulation in Maya This enables archaeologists to be able to investigate the interaction of the light with the stećak's carvings as it may have appeared in 14th century.*

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—*Animation, color, shading, shadowing and texture, virtual reality*.

## 1. Introduction

Cultural heritage is an extremely valuable set of materiality, traditions and knowledge that can be used to better understand the past itself. However, even nowadays there are still some difficulties to manage, preserve and disseminate cultural heritage sites. The use of virtual reality technology in cultural heritage is contributing decisively to reducing these difficulties [Mar01].

Virtual restoration can be used to improve the understanding of a site without resorting to interventions which are often traumatic for the original artifact. Objects which no longer exist, or objects that are damaged can be reconstructed digitally and the 3D model can then be viewed in its correct historical context.

The Department of Computer Science, University of Bristol and the Faculty of Electrical Engineering, University of Sarajevo have embarked on a joint venture to develop a system capable of achieving the three dimensional computer reconstruction and interactive high-fidelity visualization of Bosnian heritage sites. Such a system will enable archaeologists and historians to evaluate hypotheses concerning site utilization, structure, contents and development of the area.

The best known, and certainly the most valuable, monuments of medieval art in Bosnia and Herzegovina are the Stećaks. *Stećaks* are monumental gravestones, usually stone monoliths of different shapes and sizes. [Bes82].

Figure 1 shows the famous Stećak from Donje Zgošće, from the second half of 14th century. It is assumed that the Bosnian king Stjepan II who died in 1353, was buried under this stećak. This monument is currently located in the botanical garden of the BH State Museum in Sarajevo.

**Figure 1.** *Stećak from Donja Zgošća, one of the most beautiful of the Stećaks is displayed in the botanical garden of the BH State Museum in Sarajevo*

Stećaks were originally orientated from West to East, as the Bosnian Heretic Christians believed that was the way the deceased person could look at the sunrise. Nowadays, however, most of the stećaks are moved from their original locations and orientated in a wrong way. This is also the case with the stecak from Donje Zgosce which is presently orientated from East to West.

This paper presents the process of virtual reconstruction of the stećak from Donja Zgošća and the creation of a sun simulation which enables archaeologists to compare the illumination of the gravestone before and after it was moved to its new location.

In Section 2 the process of creating the virtual model is introduced. This includes laser scanning, stitching, importing into Maya and texturing the model. Section 3 explains how we created the sun simulation. Section 4 contains the comparative analysis of the rendered images of the right and wrongly orientated stećak. Finally, we conclude with a discussion of the merits of such an approach for archaeologists when reconstructing the past and present our future work in this field.

## 2. Virtual Model Creation

It is clear that computer graphics can help us better understand the past by visually recreating archaeological sites under accurate and authentic conditions. Such graphics are only scientifically valid if the components of the scene are created in an exact, scientific manner [DC01].

Methods such as 3D laser scanning and rendering with high-fidelity physics-based graphics offer a faithful way to recreate scenes from the past. In many cases, like with stećak from Donja Zgošća, the modeling of complex objects and surfaces using modeling packages and artists alone is not sufficiently accurate. Laser scanners provide a method of capturing accurate information about object's surfaces [CCG*03,Ell04]. In our work we used Minolta 910 laser scanner., as shown in Figure 2.


**Figure 2.** *Minolta 910 laser scanner is a scanner for close range and indoor applications and has an accuracy of less than a millimeter.*

Since less illuminated scan areas produce better results, the stećak was scanned during the night because of the intense light in that part of the botanical garden during daylight. Given that, the textures produced were not satisfactory, so the decision was made to continue without the original textures. Instead, the model was assigned the appropriate textures later in the Maya software.

Individual scans, created by laser scanning method, were later connected together in a polygonal mesh by using the "Stitcher" software tool provided with the laser scanner, see Figure 3. This software package performs automatic data registration, editing of captured scan data (fill holes, decimate, smooth), merging scans into a single "watertight" mesh, and exporting to a variety of 3D data formats. The final polygon mesh was then exported as a Maya OBJ file.

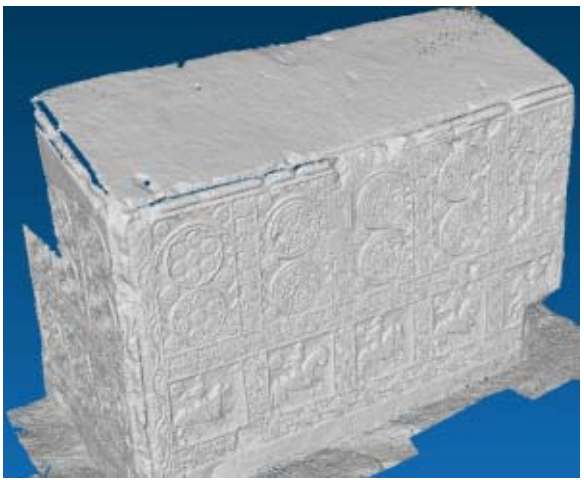

**Figure 3.** *Half of the stećak (without textures). Multiple scans merged into a single using "Stitcher"*

The computer model of the stećak was transferred from Stitcher to Maya as a polygonal mesh made up of vertices. Each vertex is a point in three-dimensional space, so is described by three orthogonal coordinates. The points are joined into faces. Any number of vertices can be joined into a face, but the scanner software only uses between three and five points per face.

Unfortunately the size of the raw data acquired by the laser scanner was simply too large to be manageable in Maya. Maya has a function to reduce the number of vertices in a polygon model. This function works with polygons created in Maya, but does not work with the polygon meshes from the scanner. A variety of methods were investigated using a small model to try and resolve this problem: Neither the `OBJ` files exported by the scanner nor Stitcher could be reduced in Maya. The only way to reduce the size of a model was to load the original file in the Stitcher and reduce it there, and then import back into Maya. This has produced slightly inferior, but still an acceptable quality model.

## 3. Maya Sun Simulation

Computer graphics enables us to place the computer model back into its original position and orientation and study how the sun would affect the stećak in its original location. [Sun03,SCM04].

We created in Maya an environment where periods of the day can be presented. The stećak was positioned on a NURBS plane. Its terrain configuration was achieved by the Sculpt Surfaces tool. We applied the Paint Effects tool to model the grass around the monument [Dwe].

The Maya Environment Sky texture was used for creating the sun simulation. This texture enables the user to achieve a realistic environment, with the sun, the sky, the clouds and the ground. It simulates the planet system observed from the Earth's viewpoint.

The Environment Sky texture in Maya has several parameters, such as sun parameters (sun brightness, halo brightness, sun size, blur, elevation, azimuth, sky brightness, ground texture and parameter, air density, dust density, clouds parameters, etc).

We animated the elevation and azimuth of the sun that was linked to a directional light, Figure 4. That way we were able to present the illumination of the stećak from sunrise until sunset.

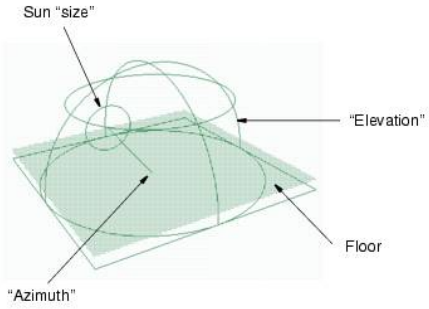


**Figure 4.** *Environment Sky texture in Maya*

## 4. Orientation versus Illumination

Stećaks were originally orientated from West to East so, as ancient Bosnians believed, the deceased person, was able to look at the sunrise.

We positioned the sun in our simulation according to that orientation and rendered the animation. Then we rotated the stećak to achieve its present orientation and rendered the animation again. Figures 5 to 8 present the illumination of the carvings and shadows in both cases, in wide shot and in close-up.

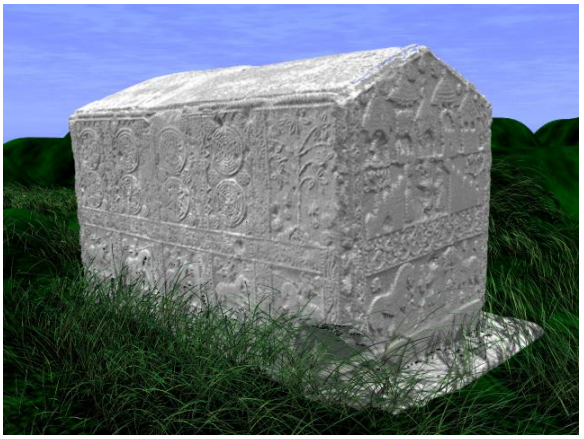

**Figure 5.** *Incorrect orientation, 11:00 – wide shot*

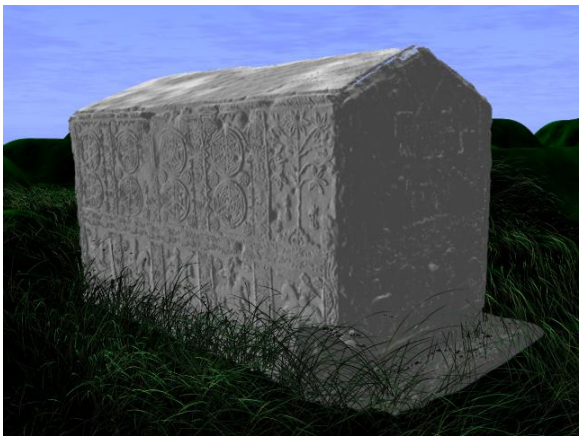

**Figure 6.** Correct orientation, 11:00 – wide shot

**Figure 7.** *Incorrect orientation, 15:00 –close up*

**Figure 8.** *Correct orientation, 15:00 –close up*

**Figure 9.** *Incorrect orientation, 12:00 –close up*

**Figure 10.** *Correct orientation, 12:00 –close up*

Clearly visible is the difference in the appearance of the carved ornaments shadows in case of the correct and incorrect orientation.

It is now up to the archaeologists to draw the conclusions about this difference and to compare different scenes presented in the carvings in both cases. There is also a possibility to observe the object in different time of the day, changing the azimuth and elevation parameters in the simulation.

## 5. Conclusion

In this paper a pipeline of high-fidelity graphics techniques for the virtual reconstruction of the Bosnian Stećak from Donja Zgošća was presented. We showed the key steps including the laser scanning, transferring of the 3D model to the Maya modeling and animation package and the animation of the sun simulation.

This project has shown the great potential and advantages of using such computer graphics techniques in the visualisation of heritage sites and objects. Archaeologists are now able to use this virtual model for verifying their assumptions related to the position of the stećaks and the influence the sun may have had on the perception of these ancient monuments.

In future work we will consider a higher, physically-based, fidelity of sun simulation using Radiance [WS98]. In Radiance it is possible to create authentic illumination according to the date and the geographic position of the object. In this we can put the position of the sky back to the 14$^{th}$ century and view the stećak as it may have appeared then.

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