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Boris Horošavin
Art historian/CG Artist

DIGITAL 3D TECHNOLOGY AND CULTURAL HERITAGE: STANDARDS AND INNOVATIONS

Abstract: In recent years cultural heritage practice has overtaken decisive steps towards new digital technologies. Various projects have been conducted in our region employing these new methods. The efficiency and utility of digital 3D technology has been proved beyond any doubt, especially considering its multipurpose character. Its implementation can be multifarious, ranging from digital scanning and documenting an object to creating elaborate 3D visualizations as a vital part of conservation project documentation.

However, conservation and restoration practice in our region isn't yet fully in tune with rapid technological development. Basic technical documentation for many significant objects is still kept in hand drawn or analogue form and concomitant photo-material is old, inadequate and practically unusable. There is a strong need for closer connection between traditional documenting, conservation and restoration processes and technical innovations. These are the main questions this article will try to answer: How to gather and process data in a manner compatible with digital techniques? What are new tools and methods in recording and documenting material? What are the benefits and advantages of implementing 3D and overall digital technology in conservation and restoration procedures?

Keywords: Cultural heritage, Digitalization, 3D technology, Architecture, Archeology

1. Introduction

During the last decade a significant breakthrough has been made when it comes to digitalization and implementation of new technologies in the domain of cultural heritage preservation. Several acclaimed projects have been realized in the region of South and South-East Europe in recent years, some of them thoroughly documented and publicly presented (notably 3D presentation of Travnik Fortress in Bosnia and Herzegovina, 3D scanning of Kosmač Fortress in Montenegro, 3D visualization of Royal Palace in Gamzigrad-Felix Romuliana etc.). Having this in mind one can conclude that the high potential and efficiency of new technologies are undeniable.

Multifunctional character – possibility for various implementations – stands out as one of the greatest advantages of digitization process. Different digitization methods and techniques can be implemented in practically every segment of preservation process workflow – from recording, archiving and documenting the material, project design and presentation to actual conservation and restoration procedures. To make it more vivid what sort of potential these methods offer we will try to illustrate it with several examples. Here is one: Practice of converting text, picture, audio and video data in digital form is commonly accepted in the contemporary documenting procedures. Material gained in this manner can be compiled in a specific interactive multimedia databases, which are easy to view and use and can be accessible to many users on different locations easily – via internet and home computer. This system – with certain variations of course – is frequently used and has been implemented in many cultural institutions, such as museums or institutes, as a sort of digital collection database. So, here we have a clear example how practical digital tools can upgrade scientific research process in terms of speed, quality and efficiency but also to contribute a wider popularization of scientific knowledge. Another interesting example for implementation a digitization technology in a domain of cultural heritage is 3D scanning of objects and terrain. Portable *3D scanner* is an apparatus very similar to digital camera except it doesn't create photo data but three-dimensional topographic print of a scanned object, a sort of digital mold which can be quite useful in specific conservation or restoration procedures. Should an architectural or sculptural object get damaged, destroyed or stolen this digital matrix can be used to create in-millimeter precise copy of that object or its missing fragment. This is achieved with help of *3D printer* (also known as CNC), machine which can process a digital print made by 3D scanner and convert it in a physical form in various materials – from plastic masses to stone. This method is also far beyond its experimental phase – it is widely accepted and commonly used in complicated restoration procedures.

Fig. 1 – Golubac Fortress, 3D presentation of existing state

Digital 3D modeling and visualization has also proved to be quite useful when it comes to project design and its presentation. The practice of forming architectural project on a computer using specific software replaced traditional pens and paper rolls. This is a natural and expected process considering the main advantages of digital method – it's far more precise, detailed and practical. With personal computer and adequate software one can view and process project material, send it by Web or simply – plot it. Another important aspect of digital project drawings – ground plans and sections – is that they can be used as basis to "raise" objects in three dimensions or, in other words to create a detailed 3D simulation of an object.

A quality three-dimensional visualization represents superior form of project presentation; it is a detailed synthesis of technical and photo documentation, geodetic and other relevant data which should result in a precise and realistic simulation of an object and its natural surrounding. In delicate situations, such as when finance and realization of a project depend on tender documentation a good project presentation can have decisive role. However, this is only one among many possibilities for implementation of 3D visualization technology; Digital 3D models of architectural, arts and archeology objects can make a basis for development of various materials: virtual museum exhibitions, interactive educational applications, publications and printed material, animations etc.

Fig. 2 – Rogljevačke Pivnice, aerial 3D presentation of proposed design

Based on the examples presented here one can conclude that there is a growing appreciation for new methods and technologies in the domain of cultural heritage preservation. However, despite of all the positive trends and conducted projects that set standards it seems as if heritage preservation practice in our region still fell behind the technological innovations in this field. This seems to be the case in sectors of documenting and archiving, which is, at least in Serbia, still bound by outdated legislation and protocols and, quite often, with paper and pen as main tools. In many cultural heritage preservation institutions archeological objects are still hand-drawn despite the fact that 3D scanning technology has become available and relatively cheap. However romantically fond of this traditional method of documenting we may be, the fact is that a hand drawing will always be rather arbitrary and imprecise and therefore – practically unusable. A similar situation is with the sector of photo-documentation where, for some reason, black-and-white format of photography survived stubbornly for decades. The glass slides are a specially peculiar phenomenon. It is a photo medium marked by good color quality and high resolution which is, unfortunately, completely incompatible with modern, digital standards. These slides are fragile and demand delicate storing and handling conditions as well as specific equipment for viewing. Since they are inappropriate for digital handling various problems can occur when they are used as a source for reproductions in printed material (books, magazines etc.) such as color distortions or overall low quality of the picture.

Regarding the problem of basic technical and photo documentation there are several things that can be done relatively quickly and don't require huge investments. Easier, though a less efficient solution is a simple conversion of paper medium material into a basic digital form via scanning. If that's the case all the drawings, photos and other material ought to be scanned in good resolution (at least 300 dpi) and preserved in an adequate digital format, such as *jpg*, *png* or *tiff*, so that it can be easily accessed and used. The obvious downside of this method is the fact that harvested material, such as text or ground plans, can only be viewed but not changed or edited. Therefore it would be more useful to digitize data in adequate, corresponding form. For example, text and other written documents should be converted into digital text via good OCR software, whereas ground-plans and other technical drawings should be redrawn in AutoCAD or some similar technical program. Finally, harvested digital material should be classified and organized in such manner to become a single, unified database with good interface that would allow fast and simple data access. Obviously, this approach would require much more effort, funds and personnel engaged on job. For this purpose research and preservation institutions could use help of young, enthusiastic and capable associates – engineering technicians, architecture students, programmers etc.

It is obvious that there is a need for closer connection between traditional documenting, conservation and restoration processes and technical innovations. These are the main questions this article will try to answer: How to gather and process data in a manner compatible with digital techniques? What are new tools and methods in recording and documenting material? What are the benefits and advantages of implementing 3D and overall digital technology in conservation and restoration procedures? The emphasis in this essay should be on 3D modeling and visualization of immobile cultural assets and therefore various examples from this area will be included, a sort of survey of standard workflow process in designing a 3D visualization.

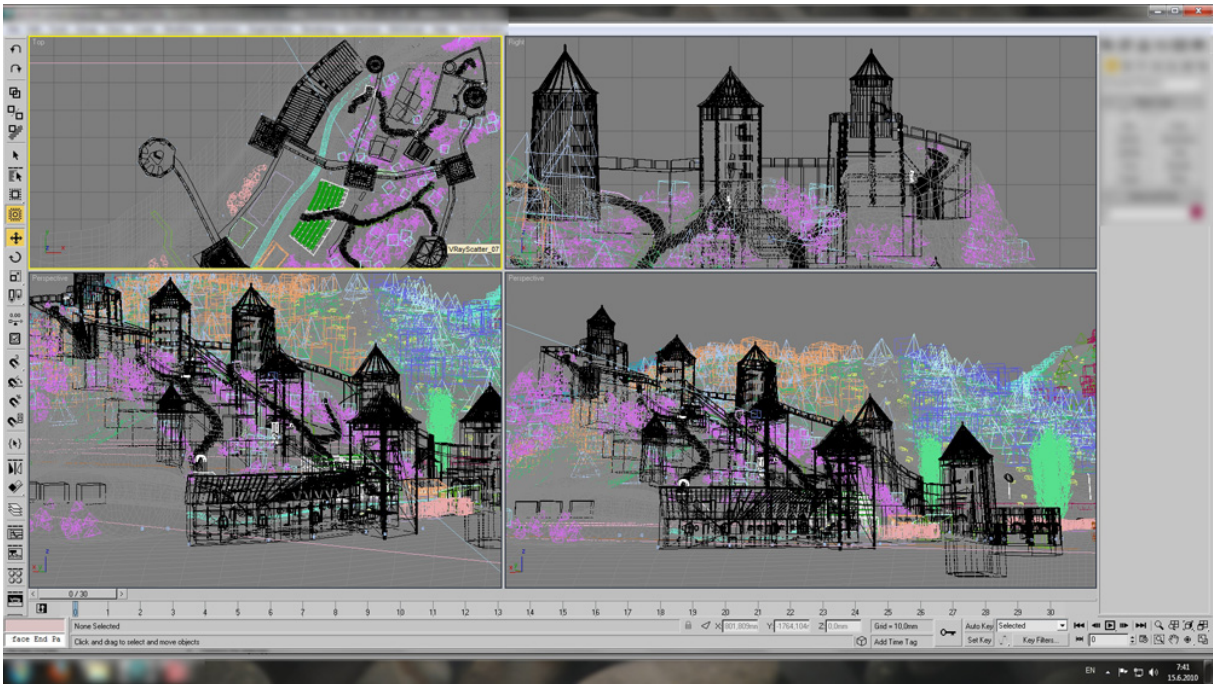

Fig. 3 – A typical 3D application workspace layout that combines ground plan and section views

2. A survey into methods and technologies

Naturally, the initial point in working process should be the direct contact with the object or – if we are talking about immobile cultural asset – field work. When working with architectural objects it is very important to have the most precise basic technical data on its physical appearance – the ground plan and sections. Usually a trained person directly measures the object to gather these data, which are afterwards converted into digital form via computer and software (AutoCAD or other similar application). Aerial ortho-photo images of high resolution can also be used for this purpose if they are given in precise proportion; in fact they are valid and admissible tool to use in General Regulation Plans in many countries. In situations when a monument is situated on a steep or inaccessible terrain and it is hard to measure it even with optical or laser devices this sort of images can be very useful. In ideal situation it would be the best to use these two methods combined: the former one for detailed measuring and the latter one as a control device that can be used to check if there is any bias and how significant it is. The downside of aerial photo technique is its high price, since a plane or a balloon is needed to make these images.

The drawings in *.dwg* or some similar format can serve as a basis for 3D modeling, a sort of digital foundation on which a full three-dimensional model of an object will be risen. Therefore it is vital that these drawings include all the important data about proportions, masses and overall physical appearance of a monument. In certain projects it's also important to have precise and detailed model of a terrain and surroundings of a monument. If so, this data should also be included in technical drawings. This geodetic information is usually represented as complex system of splines – isohypses – from which a full 3D model of terrain can be constructed. Isohypses should have high density (as small interval between adjacent lines as possible), with no blank spaces or errors in order to reach a high quality terrain model. If trained person harvests geodetic data correctly it is relatively easy to get a model of terrain via 3D application.

Another, generic and more expensive method to construct a 3D model of an object is through employment of large 3D scanners. As well as their smaller relatives these devices are used to record object from different angles thus creating the so called dot-clouds, complex digital imprints of three-dimensional appearance of the object. In the corresponding software these data are filtered and converted into a final 3D object. Though it sounds quick and easy, there are several disadvantages of this method. First of all – it is rather expensive and usually specialized companies rent these machines and personnel for reasonable or less reasonable fee. There is also the matter of errors in reading the data: during the scanning process various unwanted objects – a strong light reflection, a tree or useless annex just in front of façade – may get recorded. In final 3D model these details will occur as errors and deviations that need to be manually removed, so basically large part of the modeling is done by a trained person with computer in the end. However, the most important objection to this method is pointed to a structure of 3D model created in this manner. Unlike the 3D model designed manually in software which has logical geometrical structure consisting of cubes and facets these models have rather chaotic, usually web-like structure defined by dot-clouds. That is what makes them hard for handling and manipulation. For example, if we are working with recording of a heavily devastated monument and want to create an ideal reconstruction from it, we would have trouble manipulating model derived from the scanner; In fact, it would be much easier to create model "from scratch", manually in software.

Both of these methods, as shown, have their advantages and flaws. The 3D scanning technology is precise, but also expensive and in some aspects restrictive. In the end available resources and project manager are to decide which one will be employed. It would be fair to suggest that there are also several alternative modeling methods, most notably stereophotogrammetry. Similar to 3D scanning it uses multiple photos of an object taken from different angles which are digitally compiled and processed into a single 3D image. It is a relatively cheap method but suitable only for simple, cubical forms and objects. Nevertheless, this technique has been employed very successfully in several projects.

The next important step in the process of designing a 3D visualization is texture production. So far we have seen how to obtain basic 3D model which defines main masses and proportions of an object but not the details such as color and appearance of façade, plastic or painted decoration etc. Such fine details are achieved via textures – complex multilayered images which are applied on objects in order to achieve maximum visual appearance. Textures are created from specific photos of façade or any other detail of object that needs do be depicted. Quality texture usually consists of several high resolution photos of the same detail, known as maps, which are arranged in layers in order to achieve a realistic appearance of material (Fig. 4). The so-called *diffuse map* represents the basic layer. Basically, it is a photo in full color which defines major characteristics of material. All other maps – usually monochromatic or grayscale – are inserted under this layer and are used to define various physical qualities of material via tone differences. For example, a bump map defines relief structure of texture in a way that all lighter portions of photo represent convex structure of material, and vice versa – darker parts are concave. Specular maps use the same principle: lighter parts of image represent highly reflective surfaces opposite to darker parts which are less reflective. Almost every important physical characteristic of material – matte level, IOR (Index of Refraction), transparency, translucency etc. – can be defined using this system. With good maps and precisely tuned characteristics a texture can simulate original material in almost every detail.

Fig. 4 – Common layers of a composite texture: diffuse map, bump map and specular map

Obviously a good texture needs quality photography. This is something to take in consideration when working in field and recording a monument, because with little effort fine textures can be harvested from these photos. Here are several important tips: First of all it is vital to take a picture as orthographically as possible in order to evade any perspective distortions. Secondly, the recording should take place in the morning or early evening – in the time of day when the sun is not too bright. It is important to avoid direct sunlight which can "scorch" objects that are being recorded thus creating over-exposed portions of image or, on the other hand, strong and unnatural shadows. Finally, it is best to save a photo in adequate format and resolution – high enough to capture all the details but not too large since that could make a serious impact on memory resources of computer that process the data.

When creating a texture of a façade it is common to use the so-called seamless textures. These types of textures are created from pictures of a characteristic portion of a surface which is digitally altered in such a manner that opposite edges fit together. In this way ugly and unnatural stitches are excluded from the texture when it is being multiplied (tiled). Of course, it would be ideal to use entire façade surface for the texture and not just its random segments. This is possible, although a bit more complicated. For this the entire façade surface has to be recorded in ortho-photo technique, afterwards all the separate images must be connected and equalized into a single large map which can then be applied on the entire surface of 3D model. Textures of other parts of object, such as fresco decoration can also be created using this method. On the other hand, one could use advanced 3D scanner to do this recording job but a texture gathered in this manner is of low resolution, sometimes with some errors and inconsistencies and may not be suitable for high-quality maps.

Designing a terrain texture is a bit more complex, because it usually consists of various materials, such as grass, gravel or shrub randomly scattered. Quality ortho-photo aerial images can be used for this purpose; they have to be filtered with image editing software so that all shadows and other inconsistencies are erased. However, there is also some good plug-in software specialized in synthesizing complex terrain textures.

At this point models of object and terrain are created, as well as their corresponding textures. The last phase in making a 3D visualization is the most decisive for overall quality and effect of entire project; it includes the creation of atmospheric and direct light, calculating of shadows and production of other visual effects that contribute the photo-realistic effect of visualization (Fig. 5). Fine details that define “virtual coulisse”, such as sky with clouds or foliage and greenery are also created at this point. Finally all this material must be processed by computer in order to harvest renders – high quality images or animations (Fig. 6).

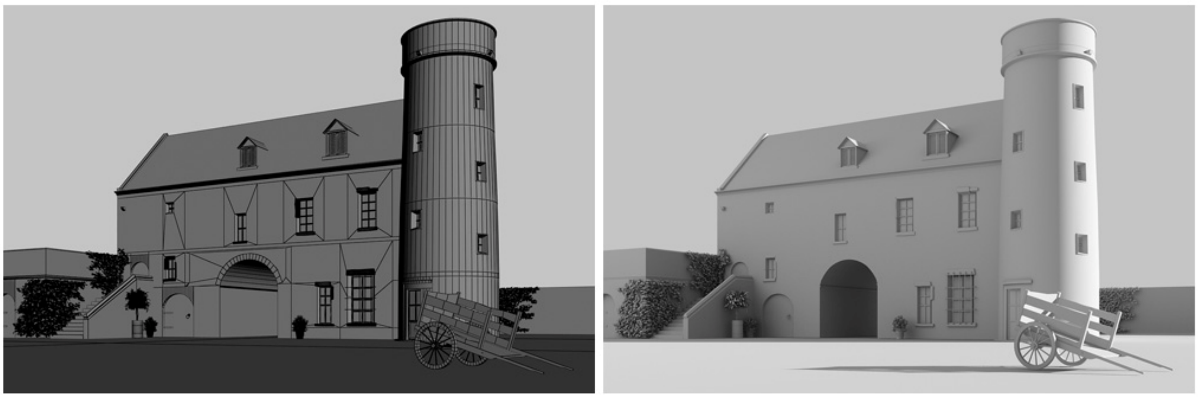

Fig. 5 – Phases in process of designing a 3D presentation:
basic 3D model (left) and scene with simple direct lights introduced (right)

3. Implementation – infinite possibilities

Final product of 3D visualization process can be used in various ways. Its basic role is to present all the vital aspects of project and its documentation in a precise, realistic and effective manner. That’s why we can say that 3D visualization functions pretty much like a digital simulation. This can be very useful and important when designing project for restoration or restitution of a monument because researchers can make simulation of their presumptions and proposals thus defining right course of the entire project. Various aspects can be checked via 3D visualization: in which technique and material the façade should be restored; where the portal originally was located; what is the exact height of a building and what was the angle of roof etc. During its synthesis with basic technical documentation a 3D visualization practically becomes its integral part. More than that, it can be manipulated, viewed from all sides and angles or interacted with. Furthermore 3D visualization can be used to derive other material in various media: printed publications, interactive animations, virtual museum or archeological site tours etc. It is important to notice that various digitization methods can be combined together thus creating powerful new tools. The ambitious Archeoguide project, originally conducted in Greece, in Olympia has demonstrated the full capacity of advanced 3D, image-tracking and mobile technology combined together. When implemented on an archeological site, this system can produce a visualization of architectural and other objects via special glasses or PDA device in real time, on the place of ruins, where these objects were originally erected. In other words, when on archeological site, a visitor can use these devices to virtually spectate objects in their original form.

Fig. 6 – A full 3D visualization of an object with textures and atmospheric effects included

4. Conclusion

Based on various examples shown here one can come to conclusion that digitization and overall modernization in domain of cultural heritage preservation does not necessarily need gargantuan investments or complicated changes in working procedures. The hardware and equipment used to harvest technical data has become advanced but also cheap enough, applications are accessible and more "user friendly". We have reviewed different methods and techniques in creating digital model, such as 3D scanning, stereophotogrammetry and traditional modeling, all of them suitable for different types of objects or levels of presentation. Above all, we have tried to outline the main advancements of digital 3D technology: speed, efficiency, fluidity and interactivity. With reasonable investments, systematization and upgrade of documentation sector environment can be created in which cultural heritage preservation can be significantly enriched and developed.

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horosavin@gmail.com