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Augmented Real-Time Virtual Environment of the Church of the Holy Trinity in Mostar

B. Ramic-Brkic [†] , Z. Karkin[‡], A. Sadzak[§], D. Selimovic[¶], & S. Rizvic[‖]

Sarajevo School of Science and Technology, Sarajevo, Bosnia and Herzegovina

Abstract

Digital storytelling significantly improves the immersion of the users into virtual environments. The perception of the information contained in the digital story is better perceived if the story is told by a real avatar, rather than the animated character. The paper describes how we improved the approach of inserting the real avatar recorded against a green screen using a sequence of images with an alpha channel in an X3D real time virtual environment.

Categories and Subject Descriptors (according to ACM CCS): I.3.0 [Computer Graphics]: General—Avatars, Digital Storytelling, Virtual Heritage; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism —Virtual reality

1. Introduction

The multireligious and multicultural environment of Bosnia and Herzegovina is a treasury of many cultural heritage monuments that belong to all nations and religions who have lived here together for centuries. Unfortunately, during the war, 1992-1995, some objects were damaged or completely destroyed. Using computer graphics techniques and 3D technologies we can recreate such objects virtually and draw the attention of the public to them, encouraging their physical reconstruction.

The virtual reconstruction of the Church of the Holy Trinity in Mostar is one example of such projects, Figure 1. The main part of the project is an interactive virtual environment (VE) of the Church. In order to enhance the immersion of the visitor, we introduced real avatars as virtual guides and storytellers. This approach was first introduced in Jovisic [Jov09], where the uncompressed audio/video files for avatars were used. In this paper we will describe how we improved that concept using image sequences with alpha channel for avatar files, making file sizes much smaller and the VE faster for download.

Figure 1: *Church of the Holy Trinity in Mostar - 3D model.*

The paper is organized as follows: in Section 2 we give an overview of the related work in the field, Section 3 describes the whole project while Section 4 explains the process of creating real avatars. In Section 5 we present our approach with image sequences, Section 6 gives the discussion on the socio-cultural impact of the project and in Section 7 we conclude and present our future work directions.

† e-mail: belma.ramic@ssst.edu.ba
‡ e-mail: zana.karkin@ssst.edu.ba
§ e-mail: aida.sadzak@ssst.edu.ba
¶ e-mail: dino.selimovic@ssst.edu.ba
‖ e-mail: selma.rizvic@ssst.edu.ba

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2. Background

Virtual Reality (VR) has great potential as a technology with social impact. One of the best explored advantages is its capability as a new medium for cultural exhibits and digital storytelling ([GCR01], [JLC*02], [BLWB03], [BDE*99], [LB04]). The aim of digital storytelling is to make the space "alive" and to share and spread the culture of a nation or country.

Brown et. al. [BDE*99] in their review of research challenges and opportunities in information technology for 2010, suggest cultural heritage as one of three main application domains for human-centered computing and VE. So far VR has been used to create a number of educational cultural experiences. Gaitatzes et. al. [GCR01] describes virtual reconstructions of the ancient city of Miletus and the Temple of Zeus in Olympia. Virtual Harlem acts as a record of the Harlem Renaissance during the 1920's and 1930's [JLC*02].

On the other hand, Augmented Reality (AR) can be viewed as a combination of distinct technologies spanning from virtual reality to computer vision [Azu97]. AR enhances the user's view of the real world by adding computer generated information [BTP*00]. In the Augmented Reality applications the virtual objects display information that the user cannot directly detect with his own senses. Various potentials of AR applications have been explored.

Currently, AR is being effectively used to communicate and promote Cultural Heritage. One such example is ARCHEOGUIDE project (Augmented Reality-based Cultural Heritage On-site GUIDE). ARCHEOGUIDE is an IST project, funded by the EU, aiming at providing a personalized electronic guide and tour assistant to cultural site visitors. The system provides on-site help and Augmented Reality reconstructions of ancient ruins, based on user's position and orientation in the cultural site, and realtime image rendering [VKT*01]. Another similar project is GEIST, where they combined augmented reality technique, digital storytelling and intelligent data query [KCS*01].

The popularity of virtual archaeology has led to a significant number of virtual reconstructions ranging from nonphotorealistic presentations, Quicktime VR images, realistic looking computer models, and augmented reality applications to fully reconstructed urban environments ([BFe00], [VKT*01], [WWAD01], [DEC03], [RD03], [STH*03], [GSM*04]).

Various applications demonstrate AR's potential in helping maintenance workers avoid buried infrastructure and structural elements as they make changes to buildings and outdoor environments [WFM*96], [RED*02]. Thomas et al. [TPG98] explored AR to visualize designs outdoors. Dunston et al. [DWBH02] have also demonstrated the value of mixed reality AR-CAD in collaborative design.

At SIGGRAPH '95, several exhibitors showed "Virtual Sets" that merge real actors with virtual backgrounds, in real time and in 3D. The actors stand in front of a large blue screen, while a computer-controlled motion camera records the scene. Since the camera's location is tracked, and the actor's motions are scripted, it is possible to digitally composite the actor into a 3D virtual background. For example, the actor might appear to stand inside a large virtual spinning ring, where only the front part of the ring covers the actor. The entertainment industry sees this as a way to reduce production costs: creating and storing sets virtually is potentially cheaper than constantly building new physical sets from scratch. The MIT Media Lab project ALIVE goes one step further by populating the environment with intelligent virtual creatures that respond to user actions [Mae95], [Azu97].

Indeed, virtual/real avatars have been extensively used for populating virtual environments in many projects. One such project is the virtual reconstruction of Travnik Fortress where avatars are used in VE in order to enhance the user's experience [Jov09].

Research has shown that the user experience is improved with natural language interactivity within the environment [WSS94]. It has also shown that the real life avatars conveyed the information with greater success than virtual avatars in virtual heritage storytelling applications [SRDC07]. Sadzak et. al in [SRDC07] used prerendered animations of real and virtual avatars in order to see whether it makes a difference who is telling the story to viewers and results indeed showed that viewers prefer real avatars.

In this paper, the major role of avatars is to tell the story about the reconstructed object and to provide us with information about certain important parts that used to be inside the object, in this case the Church of Holly Trinity in Mostar. Similar approach to digital storytelling can be found in case study of Vindolada Roman Fort where the story is describing the different scenes from the life in the fort. The video footage was composited with pre-rendered 3D environment and included into the multimedia application in the archeological museum [CREA04].

The goal of this project is to improve the immersion of the real-time VE using real avatars, based on the results from Sadzak et. al [SRDC07] and Jovisic [Jov09], but reducing the size of avatar files.

3. Virtual Reconstruction of the Church of the Holy Trinity in Mostar Project

The Church of the Holy Trinity in Mostar is of great importance for Bosnia and Herzegovina, as a religious, as well as a cultural heritage monument. Its dominating position, its size and appearance, made it one of the most beautiful and most important Orthodox buildings in Bosnia and Herzegovina and the Balkans (Figure 2). This church was completely destroyed in 1992 (Figure 3).

Figure 2: *Church before destruction.*

Figure 3: *Present appearance of the Church.*

The virtual 3D reconstruction of the Church includes creating the high quality interactive 3D model, multimedia web presentation with possibility of virtual walks through the model, multimedia DVD, 3D print of the model and a digital story. We decided to create the digital story in order to show the high quality version of the model, as the interactive version had to be optimized for the web, and therefore the quality was significantly reduced. Apart from Internet presentation, this digital content should be presented on a touchscreen display in one of the museums in Mostar.

In this Section we will describe the project in order to familiarize non-technical readers with the process of creating the virtual reconstruction of a cultural heritage object that no longer exists and the potential of its multimedia presentation.

3.1. Recreating the object

Virtual reconstruction signified reconstruction of the complete site, the cathedral and its environment. Considering the complexity of the scene, modeling process was divided in two parts, modeling the inside and modeling the outside of the cathedral, as separate modeling fragments.

The outside of the cathedral encompassed modeling the cathedral itself and its environment. The exterior of the cathedral was reconstructed primarily using information obtained from the blueprints of the ground plan, south and west facade and cross-section of the Cathedral. Those blueprints were compared to very few photographs of the monuments we were able to find. The photographs were used for modeling of complex details.

The outside of the cathedral was recreated combining 3D tools and HDR image of the surroundings of the site. 3D graphics tools (i.e. Maya software) were used to reconstruct the surrounding walls, entrance gate to the cathedral and a fraction of the terrain. In order to position the cathedral on the slopes above Mostar, the HDR image was used to contribute to the realism of the church and its environment. This picture of the surroundings / environment of the site was taken using a Spheron panoramic camera (Figure 4).

Figure 4: *The Spheron panoramic camera.*

The inside of the cathedral was reconstructed relying only on photographs, as they are the only existing material that we were able to find. Twenty four photographs were used, and they were not enough to create all the components of the interior. Therefore, it was decided to recreate areas with enough information (e.g. Iconostas) with higher level of detail, but other areas with less available information (e.g. Entrance) with a lower level of detail. Some of the interior details are created based on the appearance of the same objects in the Saborna Church in Sarajevo, built in the similar style by the same architect.

3.2. Web presentation

The intent of the web site presentation is not only to present our work but also to provide all available information on

Church's history and its destruction in order to familiarize more people with its significance, thereby promoting importance of its revival and its physical reconstruction (Figure 5).

Figure 5: *Web presentation.*

The web site is available in two languages and two alphabets, English (Latin) and Bosnian/Serbian (Cyrillic) [Sad09]. In order to display Cyrillic text properly, special encoding in the header tags needs to be specified. Windows-1251 charset, which was used in the meta-tag, allows browsers and screen readers to process Serbian Cyrillic Script as the appropriate language.

The web site contains:

- A multitude of information about the history of the Church, along with the very rare photos of its original appearance.
- An amateur-made video record on devastation of the Cathedral. This is the only available record of its destruction (Courtesy of Republic of Srpska TV Station).
- The photos of the Church ruins
- Gallery of the most valuable Church's icons.
- 3D model of the reconstructed Church available in interactive X3D format and enriched with the virtual guides and storytellers.
- Digital story with high quality renderings of the model and superimposed virtual guides.

This presentation will also be available in DVD format for offline browsing.

3.3. 3D print

The model prepared in Maya software was exported to .obj format and imported to Materialise Magics software, where model's surfaces were analyzed and fixed into a solid 3D computer model and prepared for 3D printing. The final version of the Church model was later on exported to .stl format.

The physical model was created using the monochrome Z Corporation ZPrinter 310+, with Z Print software which "sliced" the .stl CAD file into thousands of thin layers, using 300×450 dpi printing resolution.

The 3D printing process lasted for 4 hours, and post-processing (impregnation) 2 hours, therefore the final model was ready in just about 6 hours see Figure 6

Figure 6: *Printed 3D model.*

3.4. Digital story

The digital story about the Church of the Holy Trinity in Mostar is told using the same storytelling techniques as in the Virtual Sarajevo project [RS08]. We used the photos of the Church before and after it was destroyed, the amateur video of the destruction and high quality renders of our exterior and interior models. Real avatars are superimposed to the rendered images. The soundtrack consists of the voices of narrators, traditional Orthodox Christian songs and some original music compositions. We also used the sound effect of the explosion for illustrating the moment of destruction of the Church's ruins, as the Church was first burned down and then the remains were destroyed by explosive. The final sequence is exported in Flash Video format and linked to the web presentation.

We created this story in order to show the high quality model with all details, as well as to give the full visual and audio information on the events related to the church and its destruction. Also, the viewers who have no time to browse the interactive model can get a feeling of the project by watching this movie.

4. Creation of the Real Avatars

For the purpose of this project, we used two real avatars, the Orthodox priest from Mostar, Radivoje Krulj, who read the given text in the native language, and a student volunteer who read the given text in English language. Our narrators are telling short stories about the history of the Church and important interior objects that were there, such as church flags, circular stairs amvon and the episcopal tron. Therefore, we created four different scenes with real avatars

sharing stories with the viewers. Both of our narrators were dressed in traditional black clothes.

4.1. Green Screen Recording

Video footage was recorded against the green screen background. The previous experience showed that the best way was to use one fixed camera and capture the whole character, so he can be set on the planned location in the 3D environment. We used Sony HVR-Z1 camera and a set of studio lighting, Figure 7.

Figure 7: *Green screen recording set.*

4.2. Creating Alpha Channel

The video was imported into Adobe After Effects CS3 software and we used Primatte Keyer v4.0 for keying out the green background. The process of keying the material depends on the quality of the green screen set, including the background and light settings. In Figure 8 we can see an example of the source material.

Figure 8: *Video footage recorded against the green screen.*

Figure 9 shows the video material with the garbage mask applied to remove the unnecessary environment. The final result of the keying process with checker background illustrating transparency is presented in Figure 10. An avatar inserted in the virtual environment of the Church is shown in Figure 11. The output format of the video is Portable Network Graphics (.PNG)image sequence.

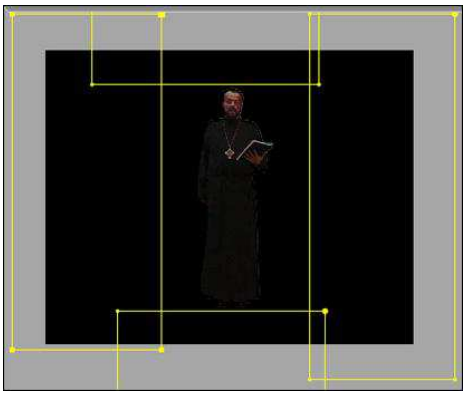

Figure 9: *Video material with the garbage mask applied.*

Figure 10: *Image with alpha channel shown as the checker background.*

5. Inserting the image sequence with alpha in x3D

In previous research, an audio/video file was always used to present virtual or real avatars. Those uncompressed AVI files occupied great amount of memory and made downloading of and moving around 3D models from Internet quite difficult and in some cases even impossible due to bad Internet connection. We could not have used any compression of AVI format, as only the uncompressed format contains alpha channel that works in X3D for extracting the character from the background.

For that reason, we are proposing use of an image sequence of .png files instead of .avi file. Difference in size is enormous and can be seen in Table 1. Taking for example just one single sequence which represents an introduction

Figure 11: *The final result of the keying process.*

about Church, difference in size between .avi file and .png sequence is 460MB.

Stories	.avi	.png	.png + sound
About Church	404.403	20.1	20.88
Amvon	481.702	23.2	23.98
Church flags	223.754	11.3	12.08
Episcopal throne	304.337	12.1	12.88

Table 1: *Difference in size between uncompressed .avi files and .png sequences presented in MB.*

Our virtual environments (VE) were in X3D format. In order to load the image sequence directly to the object that will display it, we programmed a code consisting of Touch Sensor, Time Sensor, a Script node and Routes, Figure 12.

```
<Script DEF='script' directOutput='true'>
        <field name='str' type='MFString' accessType='outputOnly'/>
        <field name='startTime_changed' type='SFTime' accessType='outputOnly'/>
        <field name='val' type='SFInt32' accessType='inputOutput'/>
        <field name='file35' type='SFNode' accessType='inputOutput'/>
        <field name='touch' type='SFBool' accessType='inputOnly'/>
        <field name='isActive' type='SFBool' accessType='inputOnly'/>

        <![CDATA[
        ecmascript:
        function touch (value) {
                if (value){
                str[0]= 'pic0.png';
                file35.url=str;
                print(str);
                }
         }

        function isActive(value, timestamp) {
                if (value == false)
                startTime_changed = timestamp;
        }

        ]]>
        </Script> <!-- end of script -->

<ROUTE fromNode='ts' fromField='touchTime' toNode='time1' toField='startTime'/>
<ROUTE fromNode='ts' fromField='isActive' toNode='SCR1' toField='touch'/>
<ROUTE fromNode='script'  fromField='str' toNode='file35' toField='set_url'/>
```

Figure 12: *Example code for loading an image on specific object.*

The touch Sensor is used to trigger the start of the animation. When the user touches an object where we placed the animation sequence (usually a box or a plane) it sends TRUE value to the Script node, which triggers the execution of the function *Touch* inside the Script node. The result of this execution is an image placed on the object. To enable this, the field *DirectOutput* inside Script node has to be set to TRUE.

The moment when the user triggers start of the animation represents starting time of the first timer. The activated timer sends TRUE value to another function inside Script node called *isActive*. This function controls the image sequence. Namely, its output is variable startTime_changed which represents end of first Time Sensor and start time of the second one, which then calls Script Node and places the next image of the sequence on the object.

Instead of the manual creation of this loop, we created a script that would generate the code automatically The script is created in C++ using Microsoft Visual Studio 2008.

The generated code could be saved in X3D file immediately or in .txt file and then copied inside the rest of the scene. This probably is an easier option since it does not require further modification of the code. Our scenes are usually more complex and consist from more than one object. Writing the code inside the script would in that case be very demanding and time consuming. A similar idea is proposed in "Kambi vrml game engine" with difference that it can be only played with certain 3D model viewer (ie view3dscene) [Kam09]. On the other hand, our code is applicable for all X3D players.

Beside decreasing the size of avatar images, we also optimized the sound of them talking. We used .wav format for sound, but reduced its size by 50% exporting it in *mono* format without having noticeable reduction in quality. Images were played 14 frames per second since it was the smallest frame rate at which the sequence could be played having in mind computers with lower performance. The sound was synchronized with the images. To further improve the atmosphere in and around the model and enhance the immersion of the viewers, traditional church music is being played in the background. This music is implemented through Proximity sensors and it starts/stops and changes the intensity with distance, Figure 13.

Figure 13: *Priest virtually placed in front of the Church.*

During implementation of this concept online, we experienced certain problems related to file size of interactive environments. Even though the size is significantly reduced

comparing to the uncompressed .avi files, some problems with downloading still remain, when the connection speed or computer performances are lower. Therefore we temporarily reduced the number of avatars in the online presentation. We will return to the original number of avatars after further optimization of the geometry of the models.

6. Discussion on the socio-cultural impact of the project

Apart from its cultural and technical aspects, this project also had a significant impact on the Bosnian society, which is still recovering from the aggression and genocide of 1990s. The public in Bosnia and Herzegovina has received it with an extremely positive response. The project presentation aroused a great media attention. Stories about the project were published in several major Bosnian newspapers and Internet portals and broadcasted at two main TV stations (BH state television and the most popular private TV network). The Orthodox religious community was grateful for the idea and provided us all possible support.

The project has a multiethnic spirit as the majority of researchers are Bosniaks (Islamic religion) and the object belongs to the Orthodox religion, so it in a way resembles the healthy spirit of Bosnia and Herzegovina, that was about to be destroyed in the war. This project shows how we can and should all work together in preservation and revival of our joint cultural heritage. It gives an important message for survival and development of the society in Bosnia and Herzegovina on the basis of mutual respect and collaboration among different nations and religions. After the tragic events of the war such projects are not many and their existence and perception in the public gives us hope for the future of our country.

7. Conclusion and Future Work

The work on the virtual reconstruction and multimedia presentation of the Church of the Holy Trinity in Mostar is still in progress. The new concept of real avatars implemented as image sequences in X3D shows good results. Virtual environments are significantly smaller in size and easier for browsing.

For future work, we plan to create a virtual treasury of valuable icons that used to be in the Church before destruction. The icons will be implemented through interactive 3D models with stories about them linked to the models. We will also create a different Iconostas in Byzantine style, as it was originally created by the Church architect Andrej Damjanov, before it was replaced with the baroque Iconostas in 1912. We will also follow the real reconstruction process through our web site.

There are still many cultural artifacts in Bosnia and Herzegovina destroyed by the war activities or simply neglected because of the shortsighted local authorities. Our future work will be directed towards their virtual reconstruction and their revival in the collective memory of the people. Hopefully it will result in their real reconstruction or at least in their presentation inside the real or virtual museums.

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