Optimization threshold in Sarajevo City Hall virtual model for Efficient Web Presentation

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Abstract

Day by day, 3D and virtual models are becoming increasingly popular in the graphic industry and many other fields. Bosnia and Herzegovina and, in particular Sarajevo, have a lot of objects that are considered to be a part of world cultural heritage importance. Many of these object were destroyed during the war in the 1990s and are still waiting for reconstruction. One way to preserve these objects and their importance is to virtually reconstruct and present them on the internet.

Internet presentation has as one of its key problems, model size which can be tackled by optimization. The goal of such techniques is to optimize a model but to avoid any perceivable quality loss. In this paper we explore the treshold of human visual perception and how this can be used in optimizing a detailed model of the Sarajevo City Hall.

Keywords: virtual model, optimization threshold, visual perception, web presentation

CCS: 1.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism – Virtual Reality

1 Introduction

Bosnia and Herzegovina has many locations containing objects that are important world heritage sites. During the aggression (1992-1995) many of them were destroyed, burned out or razed to the ground and in some cases other buildings have been built on their locations. This fact led to the creation of the Virtual Sarajevo project [1, 5] to preserve virtually many of the historic sites of Sarajevo. One of the important models in this project is the Sarajevo City Hall building.

An important goal of Virtual Sarajevo is to make the models easily available to a wide audience via the internet. In order for this to be achievable, it is crucial that each model has to be optimized as much as possible, while at the same time ensuring there was no loss in perceptual quality which the viewer will see. In this paper we describe a visual perception user study, with students aged from 19 to 22, to determine the optimization threshold for the City Hall model.

The rest of the paper is organised as follows. Section 2 provides a brief overview of 3D modeling process and its export to VRML. Section 3 offers an overview of the model optimization techniques we used. The visual perception experiments that were conducted are described in Section 4 and their results presented. Finally, in Section 5, conclusions are drawn and directions for future work presented.

2 Model creation

To create our initial models we used 3ds Max 8. Because of its complexity, the Sarajevo City Hall model was modelled using various modeling techniques, including:
- constructive solid geometry
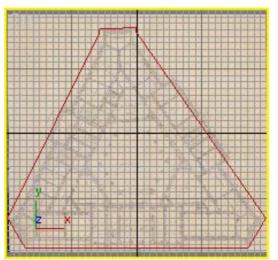- polygonal modeling
- NURBS modeling.

Figure 1: Drawing over the ground plan

2.1 Modeling techniques

The base of the building was created using a ground plan of the object shown in the Figure 1. Once the shape was made it was converted to an editable mesh and using the Extrude and Bevel tools the solid was created [2], Figure 2.
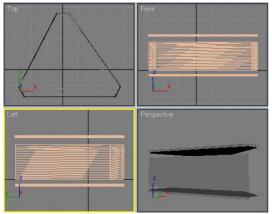
Figure 2: The extruded base of the building

The towers, arches and lilies on the top of the building were made in the same way. The entrance was modelled using the basic geometry (standard primitives) and compound objects – cubes and boolean operation.
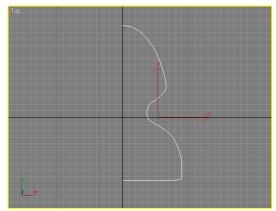

Figure 3: Drawing the that we will use to crate «skittles»

The "skittles" on the facade were modeled by creating the line which was then revolved on its axis using the Lathe modifier, Figures 3 and 4. The neighbouring houses and buildings were created using the standard primitives such as cubes and pyramids that were mapped using the photographs of the objects. The background panoramic photograph was projected on a large radius tube.
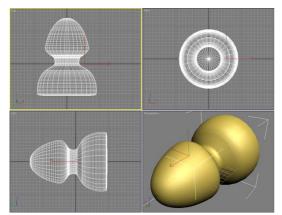

Figure 4: «Skittles» crated using the Lathe modifier

Textures for object mapping were created using the detail facade drawings and photographs. The lack of appropriate materials such as technical plans and photographs as many of these were destroyed, was a significant problem during the modeling and mapping phases. Therefore, some of the textures were created using Photoshop. This tool (Adobe Photoshop CS2) was also used for texture editing. Two types of maps were used: diffuse and bump maps, and adjusted on the objects using the UVW Mapping modifier.

For the scene illumination we used Omni (point) lights. We had three light sources on the scene: one basic light source with shadow casting and two supporting lights used as ambiental lights without shadow casting.

2.2 Export to VRML

For exporting the model in VRML we had to make the following preparations:

-helper objects creation
-shedding of bump maps

The helper objects that we used for virtual model were Navigation Info and the Background object. Navigation Info (NavInfo in 3dsMax) is very important and useful object in which we define navigation type (Walk, Fly or Examine), movement speed, users height and collision distance.

Figure 5: Detail from the facade, used as a bump map in the 3D model, and then as a diffuse map in the virtual model

As VRML does not support bump maps, we had to adjust the maps on such objects where the bump map was used. We replaced bump maps with diffuse maps, Figure 5.

Now we had a suitable virtual model of the Sarajevo City Hall building, but its size, 21.1 Mbytes, was unacceptable for the web usage, and even when used on the local computer it showed some unwanted behaviour, including temporary freezing and even disappearance of texture maps.

3 Model optimization

To provide these models to a wide audience we need to make them suitable for various kinds of web presentations. However, when using a virtual model for web presentation some limitations are imposed. The basic constraint is the model size. Reducing the size of a model is termed optimization.

The Sarajevo City Hall virtual model with its size of 21.1MB (14.9MB .wrl file and 6.2MB of maps) was unacceptable for web usage. The optimization process we conducted consisted of 3 phases:
-map optimization
-3D model optimization
-virtual model optimization

3.1 Map optimization

The first phase was the reduction of map sizes. This was done using Adobe Photoshop CS2. The size and resolution of every map was reduced to the limit where the quality loss on the model becomes recognizable. The sizes of all maps are reduced from 6.2 MB to 2.8 MB. It is important to note that each of the maps of the buildings were 512 KB large while the other 2.2 MB were used for the maps of the environment (panorama, facade, asphalt etc.). Also all bump maps are left out because VRML format does not support these maps. To avoid effusive simplicity of the model's appearance, some of the images used as diffuse maps are combined with the images that are user for bump mapping. So, instead of using bump maps for emphasizing the surface's roughness, we combined them with the objects texture to show the contours of the objects surface.

3.2 3D model optimization

This phase of optimization was made in 3ds Max using the Optimize modifier. This modifier simplifies, using a specified threshold parameters, the smooth model with plenty of faces reducing the number of edges and vertices on the object.

In order to determine this threshold so that there was no loss of perceptual quality of the resultant model, we carried out a user study. We investigated five levels of model optimization, including the original unoptimized model. We performed the optimization in a number of distinct steps.

1) First we determined all simple objects that do not need any optimization. These were the basic object such as cubes, pyramids and tubes, e.g. the neighbouring houses, their roofs, outer tube, roadside, etc. They were all selected, grouped and named "unoptimized".

2) In the second phase we deleted all indiscernible objects. Then we selected all geometry except "unoptimized" group and applied the Optimize modifier with low threshold values (Face Thresh 2.0; Edge Thresh 1.0; Bias 0.1). We noticed that some object such as the arches and cubical objects on the both sides of the entrance were deformed after optimization. We selected them, detached the modifier and added these object to the «unoptimized» group.[1]

3) In the next step we increased the optimization threshold to the following values: Face Thresh 4.0; Edge Thresh 2.0; Bias 0.1. Some additional objects became deformed, so we increased the Bias level for them to 0.3 and 0.4 depending of their needs.[2]

4) In the fourth phase we considered the objects that are far away from the user's point of view and which can thus be further optimized. So we selected the lilies on the top of the building and the "skittles" on the facade and increased the Face Thresh level to 15.0 and 10.0 respectively.

Optimization Phase	Face Thresh level	
	Most of the objects	Lilies on the roof
1	0	0
2	2	2
3	4	4
4	4	15
5	8	20

Table 1: Face Thresh used on the different objects through optimization phases

5) In the final phase of our 3D model optimization, the Face Thresh level on the first group of objects was doubled and the Edge Thresh was changed from 2.0 to 5.0. Face Thresh on the lilies was also changed to 20.0, because they are far away on the top of the roof, and on the stairs and columns to 10.0, as shown in the Table 1.

Optimization Phase	Number of vertices	Number of faces
1	406593	788026
2	226194	436747
3	164535	313373
4	125034	234412
5	113730	212137

Table 2: Face Number of vertices and faces in the model through optimization phases

All of these optimization phases were saved into five different .3ds files and exported to different .wrl files. The next step was the virtual model optimization.

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[1] After adding the Optimize modifier on the objects that use the UVWMap modifier it is necessary to put the UVWMap modifier on the top of the modifier's stack.
[2] Bias helps eliminate the skinny or degenerate triangles that occur during optimization, which can cause rendering artifacts. Higher values keep triangles from becoming degenerate [3].

3.3 Virtual model optimization

Vizx3D is a simple, visually oriented program for 3D modeling and animation [4], Figure 7. Using this program it is possible to create real-time 3D web content in the new International standard for web3D (X3D) and also in VRML97 format.
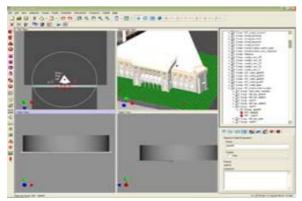

Figure 7:Screenshot of the VizX3D software with the Sarajevo City Hall imported

We made some experiments with this software and achieved very good results. We decreased the size of the virtual model from 6.5MB to 1.5MB in just few steps.

Vizx3D software does not optimize the model itself. Actually, this software does not affect the model's geometry. It optimizes the code in the file using the GZIP compression and makes the .wrl file unreadable to us, but suitable for a VRML player.

Optimization Phase – File	3D model optimization	Virtual model optimization
1	15.319	6.369
2	13.869	3.230
3	9.717	1.904
4	6.561	1.574
5	5.914	1.491

Table 3: Model file sizes through the optimization phases in KB

We made this "code optimization" to all of the five previously optimized files.

4   Visual perception experiment

The size of data transferred from the server may influence the visual quality of presented objects. Virtual scenes are always a simplification of the reality – this is especially true for web-based VR. A web presentation has to balance between the quality and speed (both speed of rendering and speed of downloading data).

We had ten different virtual models with various file sizes, and the task was to find the optimization threshold. In order to do this we performed the following visual perception experiment.

4.1 The user study

In order to carry out the experiments, we first needed to consider how to obtain the best results. First we made some pictures of the 3D and virtual model. Then we made a selection and arranged them in a random order. We presented these pictures to the subjects using Power Point. Nineteen students (10 male and 9 female) with normal, or corrected to normal vision, were subjects of the experiments. The subjects were told to select the best quality pictures in about 10 minutes [6]. The subjects were initially given instructions and shown examples as to how they could judge "quality".

In the first experiment we rendered seven pictures from the same viewpoints of all five 3D models. Then we selected five pairs and put each pair on an individual slide. The subjects were asked to write "What picture is better quality?", (Figure 8). Offered answers were:
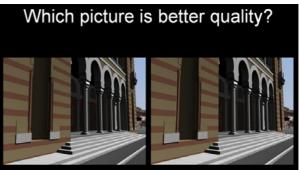-left
-right
-the same pictures [3]

Figure 8: Screenshot of the slide from the first experiment

In the second experiment we used the same process with captured pictures of the virtual model exported from 3ds Max with various level of optimization and with the virtual model exported from the VizX3D software.

The third experiment consisted of five slides with four pictures on each. All pictures were rendered from the same point of view. Now the subjects were asked "Which models are optimized (lower quality)?", Figure 9.

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[3] Subjects were provided the sheet with tables with empty fields for answers. They had to make cross in the associated field.

Figure 9: Screenshot of the slide from the third experiment

Offered answers were:

-upleft
-upright
-downleft
-downright [4]

The fourth experiment was the same as the previous one with virtual model pictures.

The last experiment was similar as the two previous but with pictures captured from different viewpoints.

4.2 Results

The following tables contain the results of the experiments. In the tables of the first two experiments, the first column indicates level of the optimization, explained in the section 3.2.[5] In the Left, Right and Same columns are the number of the answers given by the subjects.

We paid particular attention to the last step of optimization (number 5 in the following tables). We noticed the perceivable loss of quality on these models, but nothing was mentioned to the subjects.

4.2.1 First experiment results

The goal was to find the better quality image.

Pics level of optimization	Left	Right	Same
1 – 4	11	6	2
3 – 5	6	10	3
5 – 2	4	11	4
3 – 3	9	5	5
5 – 1	4	11	4

Table 4: Number of the answers given in the first experiment (see sections 3.2 and 4.1)

We can see that correct results were achieved on the first, third and fifth slides.

4.2.2 Second experiment results

This experiment used the virtual reality model's pictures.[6]

Pics level of optimization	Left	Right	Same
3 – 4	7	9	3
2 – 5	11	5	3
4* – 1	4	15	0
5 – 1	3	15	1
1 – 5	14	4	1

Table 5: Number of the answers given in the second experiment

We can see that the wrong results are achieved only on the first slide. The most optimized models are recognized as low quality like the one optimized with the VizX3D software.

4.2.3 Third experiment results

Now subjects were supposed to find optimized images.

Pics level of optimization	Up left	Up right	Down left	Down right
5–2–1–4	14	6	0	0
2-2-5-1	10	10	1	2
4–3-1–5	5	6	5	6
3–5-2-5	4	9	4	7
5–2-3-5	8	5	6	5

Table 6: Number of the answers given in the third experiment

There were many wrong answers again when testing the quality of the 3D model.

4.2.4 Fourth experiment results

Now subjects were supposed to find optimized virtual model's images.

Pics level of optimization	Up left	Up right	Down left	Down right
3-1-5-2	1	0	19	0
4-5-4*-1	1	13	8	2
1-4*-4-2	5	9	3	5
5-2-1-4*	10	1	3	12
2-5-5-4*	6	8	8	1

Table 7: Number of the answers given in the fourth experiment

These results were relevant, except the last one. We can see that the most optimized models were marked as low quality, and also the models that were optimized using VizX3D.

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[4] Multiple answers were allowed
[5] 1 – unoptimized model; 5- the most optimized model

[6] sign * indicates the file was optimized with VizX3D software

4.2.5 Fifth experiment results

The last experimental task was to mark all optimized virtual models from the twenty pictures all captured from the different viewpoints, Figure 10.
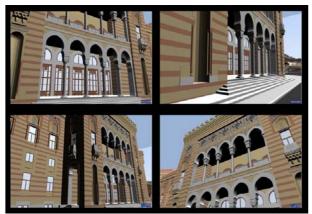

Figure 10: Screenshot of the slide from the fifth experiment

This last experiment provided the best results. It confirmed the high loss of visual quality on the most optimized models (number 5 in the tables). But this and the previous experiments also confirmed that the pictures of the model optimized using the VizX3D software were also marked as low quality.

Pics level of optimization	Up left	Up right	Down left	Down right
3-4-5-4*	3	5	8	7
4-3-5-5	2	2	9	12
4-4*-5-3	2	12	10	4
4*-2-4-5	8	4	2	10
5-3-2-4*	14	4	3	2

Table 8: Number of the answers given in the fifth experiment

After the experiments we asked subjects to show us where they noticed the lack of quality. We selected the virtual model image (5), and the picture of the image from the VizX3D (4*). The subjects showed us the following spots:

Figure 11: The spots where the subjects found some low quality details - geometry
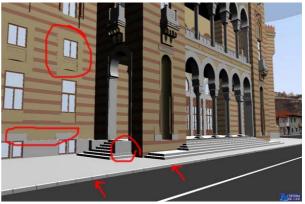

Figure 12: The spots where the subjects found some low quality details - aliasing

Then we made a zoom to these parts and compared the geometry. The geometry on the second model was much better. The reason why subjects marked these parts on the second picture, Figure 12, is because of aliasing. The problem is in rendering files exported from the VizX3D, because they have high aliasing level.

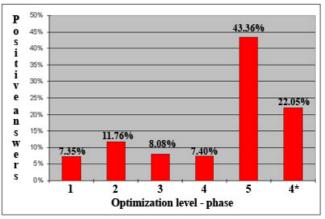These are the final results calculated from the last two experiments:

Table 9: The final percentage of the given answers for the question "Which models are optimized (lower quality)?"

5 Conclusion

This paper describes the modeling and optimization techniques in creating a virtual 3D model. It also describes a web presentation as a modern way to show arts, objects and scenes on the Internet using virtual reality.

Our goal was to find the optimization threshold on this model using visual perception experiments. Our results showed the significant difference of the image quality between the fourth and fifth phase of the model optimization and the difference in the file size was not so big. We can conclude that the optimal model is the one we got after the fourth phase of the optimization. We also discovered that the aliasing level is increased when we used the VizX3D software for optimization. However

this may be a necessary "evil" given the significant model size reduction using this system. The other thing that we could say about the model optimization is that there should be a balance between the model size and its quality. There is no certain rule where is the optimization threshold, but from our experience we may say that the optimization can be increased, with a very efficient results, to some point where the loss of the model quality is starting to be perceivable and the model size is being less decreased. In our case that was the fourth optimization phase in which we set up the Face Thresh parameter to 4 and 15, depending on the object's distance from the user's point of view.

Future work will investigate how to improve the quality of the model without increasing the models file size. It is also interesting to find out why is there more aliasing in the virtual model optimized with VizX3D and how the VRML player reads the compressed files. In addition, we will conduct a more detailed statistical analysis of our results to determine their actual statistical significance.

Acknowledgements

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