On the Edge of a Virtual World – Investigating Users' Preferences and Different Visualization Techniques

Jarkko Vatjus-Anttila, Leena Ventä-Olkkonen, and Jonna Häkkilä

Center for Internet Excellence, University of Oulu,
P.O. Box 1001, 90014 Oulu, Finland
firstname.lastname@cie.fi

Abstract. This paper investigates how the edges of a limited size 3D virtual world model can be visualized. We compared five alternative visualization techniques by conducting downloading, post-processing and rendering measurements and evaluating the designs with a user study. Recommendations for UI designers working especially in the mobile computing domain are presented.

Keywords: Virtual worlds, user interfaces, user studies.

1 Introduction

Virtual worlds (VWs), or virtual environments, utilizing 3D graphics are familiar for large audiences mostly from game domain, e.g. from online games such as World of Warcraft. In addition to imaginary landscapes, increasing amount of work is done for creating 3D models and virtual world representations of our everyday environments e.g. for city architecture or interior design of apartments. Although 3D virtual worlds can be made to represent the real world exceedingly well, the models come with an inherent design challenge – they are limited in size.

Bringing the user to the edge of the virtual world model can create a visualization and user experience problem, and the model may appear e.g. to float in space, Figure 1. This is especially true for outdoor virtual world representations, where, contrary to indoor spaces, the walls do not create a naturally confined space. Moreover, especially with mobile devices, the processing power and data transfer capability set limitations. The graphics in the virtual world representations are often heavy for both of these requirements, and the technical feasibility and its effect on the user experience needs to be taken into account, when designing VW applications for mobile domain.

In the area of designing virtual world user interfaces (UIs), earlier research has examined, e.g., avatars [7], text readability in 3D games [4], and collaborative and shared space aspects [5]. In this paper, we examine the design challenge of visualizing the edges, or outer boundaries, of virtual worlds by examining the initial user perceptions as well as technical characteristics of alternative designs. To best of our knowledge, our paper is first one to address the topic of virtual world edges. Our research contributes novel knowledge for VW UX research, and can impact to the UI design of 3D virtual world applications especially for mobile devices.

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2 Studied Visualizations

For the study, five alternative visualizations demonstrating the edge of a 3D virtual world were created: A. Wall, B. Forest, C. Soil map, D Road map, E. Island, see Figure 1 A-E (for the 3D city model). These were selected to cover wide range of different visualizations used currently in games and other virtual world environments.

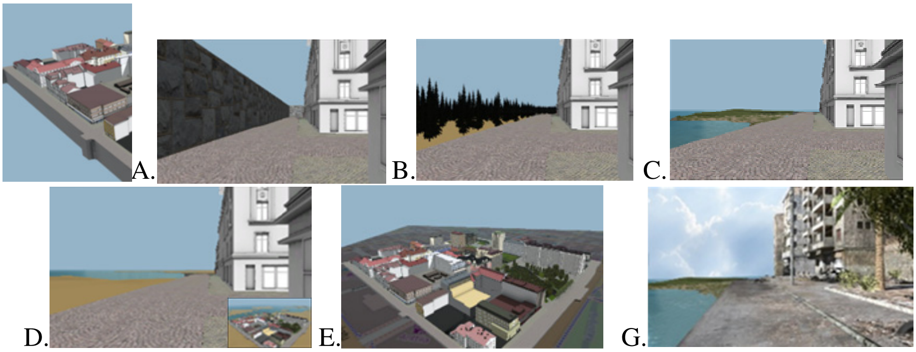

Fig. 1. Virtual world model, which appears to float in the space (top left), visualization types A-E created for virtual world edges, and example of the game world (G).

Technically, the process of loading 3D content into the client device, e.g. a PC or smart phone, can be split into three separate phases; first, the downloading phase, where all necessary 3D content is being downloaded from the remote service; second, post-processing phase, where the content is modified locally in the device if needed (i.e. content generation); and third, the actual rendering of the 3D scene.

Wall scenario encapsulates the 3D scene into fixed boundaries, which allows the client to utilize rendering optimizations to it, i.e. occlusion culling [8]. The *wall* was chosen as the simplest way to confine a limited area. The geometry of the 3D model of the wall is very simple, making the downloading time short and rendering simple.

Forest. Here, the terrain soil is used as the basis for a generated forest, and needs to be downloaded to match the real-world landscape. The 3D trees, selected to roughly match to the climate in Oulu, were generated from a single tree model, which was downloaded and multiplied in post-processing. Here, occlusion culling optimization is harder than with *wall* as the forest is sparse.

Soil Map. This scenario is based on the real world landscape, and is similar to the forest scenario but without the trees. Instead, a water simulation is generated to bring vividness to the view. No occlusion exists since there are no solid obstacles in the boundaries of the space. However, the terrain soil itself can be GeoMipMapped [1] to achieve better rendering performance in this scenario. The scenario can utilize the information from other geographical data sources.

Road map utilizes a very simple geometry under the city which then uses a single image to represent the city map for the user. Downloading wise the case is consuming not because of the geometry but the map details, which need to be high in order to give the clear enough view for the user. There is no need for post-processing.

In **Island** scenario, almost everything is created in the post-processing phase. In this game world type approach, the terrain soil is mathematically generated using perlin noise [6] and only its generation parameters are downloaded from the remote service.

Two alternative VW designs were presented: the 3D model of Oulu city, and a screenshot from an imaginary virtual world in Serious Sam game. Here, see Figure 1 G for the game world example and Fig. 1 C for corresponding city model.

3 User Study

To study the users' perceptions, we examined the five visualization techniques for the real world and game world, illustrated in Figure 1. All the pictures were demonstrating a street view from a walker's perspective. However, to make the soil- and road map visualizations more clear and understandable, an overview picture of a 3D world with its surroundings was also presented. Each alternative visualization was presented in the questionnaire as a picture along with 7-point Likert scale evaluation of pleasantness, following by an open question about justifying the given score or free comments. After five optional visualizations (which could be viewed simultaneously when assessing the designs), we asked users which visualization they liked most and least. This was repeated in both (3D model of the city of Oulu and imaginary 3D virtual world) cases. To avoid the bias, we counterbalanced the task so that half to the users started with the real world 3D model, half with the game world visualizations. Prior to the study, participants were shown a virtual walk around the 3D city model without any visualization of the VW boundaries, i.e. as in Figure 1 (top left). This was done with a tablet device.

Altogether 32 participants (11 female), aged 22-40 (average 28), took part to this study. As a background, 15/32 reported of playing computer games with a 3D virtual world. All participants lived in the city area and were familiar with the 3D city scene.

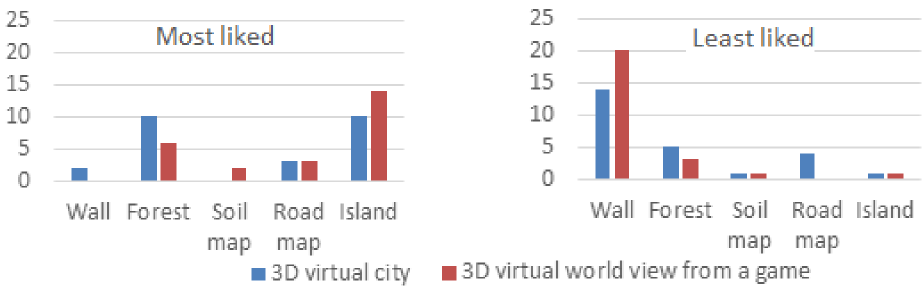

Fig. 2. Most liked (left) and least liked (right) visualizations (n=25)

The results for the most and least liked visualizations are presented in Figure 2 (25 answers in total). The most liked visualizations were the **forest** and the **island** for 3D city model, and the island for the game world. Also when participants assessed the pleasantness of the scenarios (7-point Likert scale), the island was considered most pleasant with both 3D virtual worlds. Average value of the pleasantness of the island visualization with Oulu 3D model was 5 (stdev 1,72) and with game view 4,97 (stdev 1,85).

The visualizations using the themes from the nature, such as forest, sea or mountains, were considered pleasant. The forest visualization was considered to be more realistic than some other versions, at least with the 3D city model: *"It's more like the real view, Oulu city is surrounded by the forest after all (#29)"*. From the comments it was evident that also the visualization of island was perceived to be a nature landscape. The sea view with a bit of a green grass was considered as relaxing: *"Nice view, tranquil, gives you a good feeling (#31)"*. Also the impression of wideness together with the sea was considered pleasant. *"I like the sea view and open areas (#10)."* Users were more unanimous when choosing the least liked scenario, see Figure 2. Nine of the 32 participants verbalized that the wall looked like a prison wall or made them feel like trapped. "*I feel like I am in prison*. (#31)" In addition, some users considered the wall to being simply boring and un-realistic: "*It is good to show boundary wall, but in practice no such walls exist, so there should be something else [visualized]*. (#25)"

The idea of the 3D virtual mirror world continuing from the edge in a format of a map was perceived interesting, but useless and unpleasant for the user on the perspective of a walker in the street. *Soil map* was seen realistic and giving true information from the environment, but again the visualization was not considered pleasant. On the other hand, some participants had difficulties in associating the *soil map* with the real world geography, but treated it as the imaginary *island* landscape.

4 Technical Measurements

To investigate the technical aspects and compare them with the user study results, we conducted downloading, post-processing and rendering measurements with the visualizations. These were done using a PC with Core I7-3770 Central Processing Unit (CPU). Downloading was done using local WCDMA/HSDPA network. Because the 3D city model was the same for all of the scenarios, it was not included in the downloading times, but instead we compared the delta between downloading times of the specific 3D assets for each scenario. Threading was not used and hence the post-processing started after the download phase was finished. Regular rendering optimizations, such as the occlusion culling, were performed. Rendering complexity was measured in terms of visible triangles and required drawcalls, which are both important performance factors. Each scenario was processed 50 times, and the results in the Figures 3 and 4 present an average for a single test run.

Figure 3 shows the download and processing times for each visualization. The lowest download time takes place with *island* scenario, which is evident since only a few parameter files were downloaded for the post-processing phase. *Wall* and *road map* visualizations are the second fastest due to their simple representation model. *Forest* and *soil map* visualizations took longer to download primarily for the terrain soil component. Post-processing affected the most in *island* scenario, since practically the whole visualization was generated from the scratch. In the *forest* scenario, the post-processing took care of the tree generation, which was much simpler that the terrain generation in the *island* scenario.

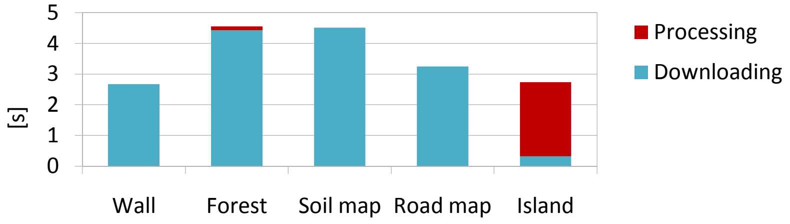

Fig. 3. Cumulative downloading and processing times for each visualization

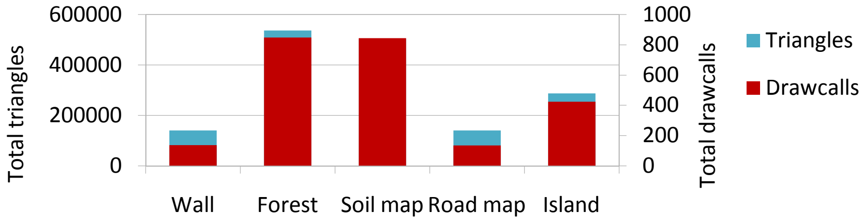

Fig. 4. Rendering complexity for each visualization

Figure 4 shows differences in the rendering complexity. The *wall* and *road map* visualizations were the simplest to render due occlusion culling opportunity (*wall*) and low geometry detail (*wall, road map*), which can be seen from both low triangle count and drawcall count. Forest and soil map visualization were both very heavy due to the terrain soil and no opportunity for the occlusion culling. In the forest scenario, there occurred some amount of occlusion, but its effect is neglected due to the added geometry in the forest itself. The benefit of the island scenario lies in the generation algorithm which was able to create dynamic level of detail [2] to the soil, which allowed the same surface area to be filled with less geometry. This is clearly a benefit of any generation algorithm, which can optimize the data to the client device.

5 Discussion and Conclusions

Based on our findings, it is recommended that the VW application designers should not go blindly towards the optimal technical solutions, but take into account the other factors that influence the user experience – here, the best option in technical sense, *the wall*, was the least preferred by the user study participants. On the other hand, the results indicate that it is possible to generate visualizations that are pleasant for the user but require small amount of downloaded data (*island)* or little post-processing (*forest*). This way, optimal solutions can be found for different technical settings. Based on our user study, we were able to derive the design recommendations for visualizing the outer boundaries of a 3D virtual world presented in Table 1.

Table 1. Desired characteristics for the visualization of 3D virtual world boundaries

Realistic	The design should fit to the VW environment and match with people's mental model of the physical world.
Natural	Themes from the nature, e.g. mountains, forests, water, are perceived pleasant
Open space	Rather use an open space, not narrow and closed
Pleasant to watch	Aesthetics plays a significant role in user perceptions
Provide additional information	Providing context information is appreciated in cases where that is possible.

The CPU used in the measurements was rather fast, and due to vast processing power does not compare to the mobile CPUs. Hence, the post-processing time appears fast. However, as we sought to explore the delta between the different techniques, we argue these results are reusable also for the mobile clients showing the scale of effect what to expect. Early research on location-aware mobile services studied in-the-wild has reported that the (too long) downloading times caused frustration for every participant (n=20) and was a central issue in resulting negative experiences with the service [3]. This aspect was not yet explored in the user study, but would be an interesting topic for the future user studies. We acknowledge that the laboratory setting for the user study does not necessarily fully reflect the user perceptions in the real life use context, and that the selected city (e.g. presence of the water) can influence to the perceptions. The results are preliminary, but nonetheless, we believe that they still provide interesting insight to the design challenge. Our plan for future work is to conduct a study *in situ* at the city center, with a mobile device.

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