The World's Tallest Plants in a Single Glasshouse: Creating a Utopian Virtual Reality Diorama

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Abstract: After decades of development, virtual reality (VR) systems for the masses seem finally just around the corner. This paper presents a practical opportunity for the use of VR in a botanical museum context using a popular game engine and an already available developer version of a head-mounted display. The authors describe the creation of the VR exhibit, a fantastic landscape accessible with roller coaster ride amidst an impressive glasshouse with lifelike 3D plants. It also examines the merits and limitations of this VR diorama including some preliminary results from user feedback.

Keywords: Virtual reality, virtual environments, 3D plants, game engines, museums

1 Introduction

The Botanical Garden Berlin-Dahlem counts as one of the most important botanical gardens in the world being one of the largest in terms of both area (43 ha) and variety of its plants (over 20,000). In 1889, it was the plan of the first director and German botanist Adolf Engler to create "The world in a single garden" (LACK 2000). There are several buildings and glasshouses such as the Cactus Pavilion or the main tropical greenhouse in Art Nouveau style, which is one of the largest historical glasshouses in the world (60 m width, 23 m height). The institution also houses the Botanical Museum. Amongst many other objects, it comprises a series of impressive landscape dioramas in the form of miniature, artificial, three-dimensional landscapes enclosed in a glass showcase.

In 2014, the head of the exhibitions and museum invited some of the authors to contribute with a virtual reality (VR) 3D model to their special exhibition 2015/2016 named "modelSHOW" (GROTZ 2015). The exhibition focuses on botanical models as well on biological and didactical models in a broader sense. The exhibition explores both the perception and creation of objects and the issue of what models can achieve today. The museum aimed to transfer their main intention of didactic mediation into a contemporary context by new technical means. While most of the exhibition items comprise of physical objects such as glass, wax, or even Lego® models of plants, others include digital or digitally produced objects such as 3D prints of plant structures, video art, or computer-generated illustrations of blossoms.

Some of the authors were commissioned to conceptualize and build one of the interactive stations. The goal was to develop an exhibit supporting a story-centric experience that would transform the museums visitor from passive viewers and readers into active players by means of VR (WOJCIECHOWSKI et al. 2004). The idea was born to adopt the concept of the landscape dioramas and reinterpret them for the digital world – a virtual reality diorama – which, in contrast to physically built dioramas, e. g., in natural history museums (QUINN 2006), would be virtually accessible. This virtual reality diorama should meet the essential characteristics of VR – "that it should be Illustrative, Immersive, Interactive, Intuitive and Intensive"

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(ORLAND 2001). Furthermore, the exhibition organizer expected a game-like environment of something that cannot be "physically" experienced in the botanical garden and would attract especially younger visitor while being easy enough to be used by elder people, and young children, too. Navigation should therefore be kept simple, so the exhibit is as self-explanatory as possible.

2 Developing the Virtual Diorama Exhibit

2.1 Material and Virtual Diorama Design

A brainstorming process with the museum's head revealed that one of the most promising ideas would be an exhibit showing plants that are particularly large. We then compiled a selective list of the worldwide largest plants, i. e., mainly tallest tree species and specimens (WIKIPEDIA 2016). A few of these grow in the local Botanical Garden, e. g., Caucasian fir (*Abies nordmanniana*), in the main tropical glasshouse, e. g., Kapok tree (*Ceiba pentandra,* Figure 1), giant bamboo (*Dendrocalamus giganteus*), or are presented in the museum, e. g., a trunk disk of an old coast redwood (*Sequoia sempervirens*). Nevertheless, many of botanical giants either cannot be shown as live plants in the Botanical Garden or do not come close to the dimensions or typical habitus of their relatives in natural habitats. In addition to the main criterion "exceptional size", the selection should also include common tree species from Germany and Europe, which are widely known, e. g., English oak (*Quercus robur*) and stone pine (*Pinus pinea*), even if they are not as big as world record holders, because of their recognition value and as reference for tree heights. Moreover, the list includes trees with characteristic habitus (tree species should easily be distinguishable from each other, e. g., stone pine), at least one tree from every continent, and one tree (*Abies nordmanniana*) from the Caucasus (which is one of the main focus areas of the Botanical Garden Berlin for biodiversity research).

Fig. 1: References for the 3D model of the Kapok tree (*Ceiba pentandra*) found in the Singapore Botanic Gardens (Photos: Author)

Inspired by the motto “The world in a single garden”, we elaborated the concept of an imaginary environment, a designed space, which is bringing together ten of the largest plants in the world from various regions and climate zones in one (virtual) location – a colossal glasshouse of 150 m height (Figure 2). A utopian place especially because the plant species wouldn’t grow together under one roof.

The botanical giants are modeled in 3D combining procedural techniques with handcrafted details (DEUSSEN & LINTERMANN 2005), each in their maximum height of living specimen, as measured officially. Photos from living specimens at the Botanical Garden Berlin were taken in the botanical gardens of Berlin and Singapore (Figure 1) for both reference and source material for textures of the 3D plants. For performance and memory reasons, we applied semiautomatic Level-of-Detail (LoD) control on the 3D trees using parts of the framework for hierarchical billboard clouds generation (KRATT et al. 2014).

The architect and 3D artist Thomas Vournazos (slashcube.net) was commissioned to create the virtual building. His design was inspired by the architectonical masterpiece of the local tropical and Victorian style glasshouse architecture. The park-like outdoor landscape consists of lawn areas and woodland, represented by temperate 3D trees. The outdoor in autumn aspect creates a colorful contrast to the luscious green indoor.

2.2 Apparatus and VR Scene Setup

The museum supported our idea of using a VR head-mounted display (HMD) as interactive viewing device. Therefore, the virtual reality system consists of four main components: a game engine running the virtual environment, a workstation with a fast gaming graphics card, a HMD device, and a built seat for the visitor. For the technical implementation, we have evaluated game engines suitable for landscape visualization (KRETZLER 2006) that already support the HMD Oculus Rift Developer Kit 2 (OCULUS VR 2016). First tests with the popular game engines Unity 5 (UNITY TECHNOLOGIES 2016) and 3D trees with more than 100 k polygons resulted in very slow frame rates (< 5 FPS).

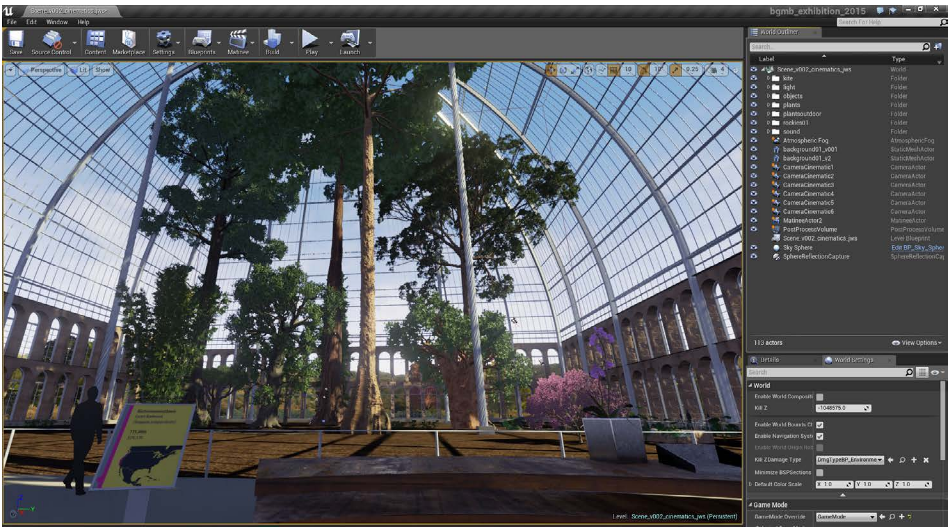

Fig. 2: Screenshot of the Unreal Editor scene

This made us switch to the Unreal Engine (UE4) developed by Epic Games (2016), which is free of charge for project visualizations and supports 3D objects with more than 64k vertices, suitable for fast display of – what in game design are called – "hero trees" (detailed 3D trees for the foreground). Our artist imported the 3D plant models, the building, the virtual carriage, and other assets into the Unreal editor. He also applied and adapted *Shader* programs, most commonly used to produce lighting and shadow in 3D scenes, as well as for visual effects, and level-of detail blending. The VR system runs on a state-of-art PC with a 6 GB NVidia Titan graphics card. Based on experiences made at a former interactive exhibit (SEILER 2005) especially with elder visitors and due to pragmatic considerations, we decided to minimize the required user interaction. Therefore, an infinite roller coaster loop from the ground of the glasshouse to the treetops and back has been implemented. A script was written in Unreal to layout the tracks procedurally. A visitor just has to take a seat in a physically, but also virtually built "carriage" (Figure 4) and put the Rift on his/her head. A Full HD monitor mirrored the Rift's display for the left and right eye for any bystanders but limited to non-stereoscopic display.

Initially, labels for each of the giant plant specimens were supposed to pop up when a user would closely approach a plant. The technical implementation for these labels has not been satisfactory because there were too hard to read from the moving carriage and therefore hidden. Thus, the embedded didactic information on knowledge of the specific plants felt shorter than originally planned. Alternatively, short fact sheets about each plant species including a map of their natural distribution have been printed and placed next to the exhibit to circumvent the missing feature.

Besides the contribution from the architect, mainly one developer and one 3D artist have been working for 4 month on the project. The exhibition designer created the carriage.

3 Results

The result[1] is a genuine virtual environment with a naturalistic look but something that cannot be built in reality due to physical-technical and biological restrictions. The immersive ride in 3D stereo enables the visitor to look around by 360° and explore at slow speed the plant giants, and the indoor and outdoor environment. While the ten plants are kind of facsimiles of their natural paragons, they are not direct replicas, i. e., not virtual "casts" of real trees, e. g., from model-makers or from 3D scanning. Instead the 3D plants models can be described as a collage, a composition and interpretation of real plants. It is more an attempt to depict a clearly recognizable habitus, characteristic for the species at maturity than the exact reproduction of an individual specimen. The results are curated models with idealized growth pattern and some compromises and shortcomings, e. g., caused by limitations of the game engine, or our modeling tools for the plants.

The frame rate was about 20 or more frames per sec. Based on the feedback from visitors, e. g., the exhibition guestbook, personal conversations, and observations of the museum's staff, the audience is generally excited about the VR exhibit. Children and teenagers love it! An estimated third of the visitors tried it. The VR HMD and the carriage design seem to attract rather "digitally skilled and minded", video gamers, or particularly curious visitors

[1] video clip: https://vimeo.com/139475490

but especially elder people tend to ignore the exhibit. After reading the warning sign about motion sickness etc., some interested visitors, mainly women or parents with their young children shy away from testing it. However, there is no feedback from users that somebody has suffered from dizziness, or motion sickness. It has been observed that being seated in both the real and the virtual space reduces the potential discomfort reactions.

Fig. 3: Screenshot of the trajectory in the virtual glasshouse

A number (54) of interviewed visitors have reflected upon their experiences of using the VR exhibit. In general, visitors were impressed by the majesty of the plants and indicated a high enjoyment rate (mean value 6 on a Likert scale from one to seven). Some comments addressed technical limitations or drawbacks of the VR system, mainly originating from the Rift DK2, e. g., a high latency time especially while looking around, the visible pixels / low resolution, and the heavy weight of the Rift. Other statements criticized a few aspects of the design and setup of the virtual environment: the low density of the vegetation on the ground and the slow speed of the roller coaster. Four Children mentioned that they would have expected to see their body in the virtual environment, too.

Mainly children and teenagers suggested an accelerator pedal for an individual speed, sharper curves, or even steeper gradients of the track. Some users have suggested advanced interactive feature such as *haptics*, e. g., touching twigs (even with force-feedback) or stopping the roller coaster. Primary school pupils were observed a few times at the exhibition trying to maximize the suggested radius of movement but still limited by the cable of the Rift. After their ride, they replied that there were curious if one could fall down the carriage. Some visitors have emphasized the pleasant entertaining and playful character of the exhibit.

Fig. 4: Photos of the VR exhibit and users at the exhibition

4 Conclusions and Outlook

The museum is impressed about the widespread possibilities and potentials for new didactical models, and virtually accessible landscape dioramas with life-size models inside a VR headset. The VR diorama realized focuses more on sensation, the immersive experience, the exploration of the environment, and the aesthetic qualities than on the active mediation of learning contents. The exhibit has been one of the highlights of the exhibition and one that attracts a younger audience. Part of the fascination observed with the VR exhibit can be explained by the high rate of “VR novices” and that in 2015/2016 Oculus Rift and VR are media-hyped. One downside of the HMD solution is that it is – in contrast to a VR theatre – a single user experience.

We have not interviewed enough visitors to further evaluate the exhibit, e. g., the relationship between the sense of “being there” in VR and enjoyment, which correlate in a study by SYLAIOU et al. (2010).

How could such an exhibit be improved? The VR diorama could be extended with interactive game and quiz features, such as a hunt for things or identifying species. Some of the advanced interactive features are technically feasible in Unreal engine based scenes but would require more sensors or other human-machine interaction devices. Other shortcomings such as high latency time or low frame rates will probably soon be technically solved by the hard- and software industry. Meanwhile, the pre-rendering of interactive 360° stereoscopic video, e. g., in the UE4’s inbuilt movie tool “Matinee”, would be an alternative to the interactive rendering realized on the high-end workstation. It would result in even higher graphics quality with a constantly high frame rate running on inexpensive PC hardware.

Recently, we have created a (free) grapevine 3D model for UE4. It has been downloaded over a hundred times and used in the 2015 UE4 competition “The Vineyard Challenge”[2],

[2] http://www.ronenbekerman.com/challenges/the-vineyard-challenge/vineyard-challenge-entries/

which shows inspiring results of animated landscape visualizations mainly created by 3D artists and architects.

BARTH (2015) is asking: Will landscape architects be ready for VR? In our opinion, UE4 is an attractive tool for landscape architects, too. Its ease of use paired with both its graphics power and quality, and the interface for VR headsets make it worth testing! If you don't intend to create a commercial game, then the price of UE4 is just unbeatable.

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