Hanging Gardens: A City Crown for Halle by Walter Gropius in Virtual Reality

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Abstract: As part of the project "Hanging Gardens – A City Crown for Halle by Walter Gropius in Virtual Reality", a central building project of Classical Modernism can be experienced and walked through for the first time, which – had it actually been built – would have made the city of Halle known worldwide as a centre of Bauhaus architecture. The article provides insights into the development, design and implementation of the interactive VR installations. The basis is formed by 15 preserved original drawings and years of research work. Over several steps, the topography of the area was built up, the 92-year-old drawings interpreted and digitally recreated, and 3D models developed and visualised.

Keywords: Virtual and Augmented Reality, simulation, georeferencing

1 Introduction

The impressive architectural design by Walter Gropius for the city of Halle (Saale) was made tangible for the first time in the interactive exhibition project "Hanging Gardens – A City Crown for Halle", shown from 15 September 2019 to 19 January 2020. The exhibition takes the form of a walk-in VR-installation. After years of research and an elaborate digital reconstruction, visitors could experience the spectacular, although never carried out, architectural design on the Lehmannsfelsen in Halle. The interdisciplinary research and exhibition project thus makes the design virtually visible 92 years after its becoming, and not far from the originally intended location.

The exhibition gives an insight into how the Hanging Gardens would have looked. Architect and founder of the Bauhaus Walter Gropius (1883-1969) submitted this design to a competition for a so-called city crown for Halle with a city hall, a museum and a sports forum in 1927 (FUHRMANN 2019). With a graphic 3D-interface, the visitors could view the complete area in miniature; they could teleport from one position to another or move freely within the digital model via controllers. Multiple VR-stations and a large-screen projection offered insights. The exhibition "Hanging Gardens – a City Crown for Halle" offers the three-dimensional and impressive virtual experience of the design. Special attention was given to the room concept of the concert hall.

The base for the realization of the project were 15 original drawings as well as long-lasting research. The topography of the location was constructed in several steps, then interpreted in 2D-models, and finally digitalized and transferred into 3D-models. The positioning and dimensions of the design were made fathomable during site visits with augmented-reality applications and 360-degree-videos. There are images and 360-degrees panoramas for particularly compelling locations. An extensive accompanying program with guided tours, lectures and workshops deepened and expanded the topics of the presentation. The results from the discussion forums and workshops became part of the exhibition and constantly changed its content and form.

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Fig. 1: Exhibition project "Hanging Gardens – A City Crown for Halle from Walter Gropius in virtual reality"

2 New Design and Content Accents in Landscape Architecture

It's obvious: The open space design that Gropius designed for the contribution Hanging Gardens lies outside the classical appearance of 1920s landscape architecture. With this design, he sets new accents in open space planning in terms of content[1] and design.

For Gropius, the Hanging Gardens above the river Saale represent a new landmark for the city of Halle (GROPIUS 1928). The competition area was already connected to a grown urban quarter and thus close to the city center. And yet the still undeveloped Lehmannsfelsen is in the midst of nature. Gropius places an urban master plan in this idyll, which at first glance embodies above all the ideas of architecture and technology discussed at the Bauhaus in Dessau.

The plan graphics don't show the great natural scenery above the Saale floodplains. Instead, Gropius develops the concept out of the traffic plan, describes access and exit routes for cars, puts bus traffic on the promenade on the banks of the Saale and creates one hundred parking spaces. Gropius deliberately refrains from drawing gardens and landscapes in order not to "interfere with the clear assessment of architectural bodies" (GROPIUS 1928). Only rows of trees, not shown in green but in blue, serve as local boundaries for the entire ensemble or form the transition from architecture to landscape. The design is characterized by different levels of open space design, described by Gropius himself in 1930: "the use of accessible roof gardens with plants is an effective means of incorporating nature into the stony deserts of large cities. The cities of the future with their gardens on terraces and roofs – seen from the air – will give the impression of a large garden" (GROPIUS 1974).

Among the contribution submitted for the competition, Walter Gropius' large-format design drawings entitled "Hanging Gardens" stand out both conceptually and in their radical formal language. The partially colored blueprints submitted in Halle are now kept in the estate of Walter Gropius at the Busch-Reisinger Museum in Cambridge, USA. They were given a logo in the upper left corner consisting of three circles in the Bauhaus colors yellow, red and blue

[1] The competition and Walter Gropius' contribution were extensively studied and analysed for the first time as part of a research project by the author. Cf. Christine Fuhrmann: Eine Stadtkrone für Halle a. d. Saale by Walter Gropius, (Dissertationsschrift) Bauhaus-Universitätsverlag Weimar 2019.

and the motto Hanging Gardens. The original drawings were severely damaged when they returned to the Bauhaus Archive Berlin after the death of Walter Gropius. Here they were rediscovered, documented and scientifically interpreted as part of the research work in 2007.

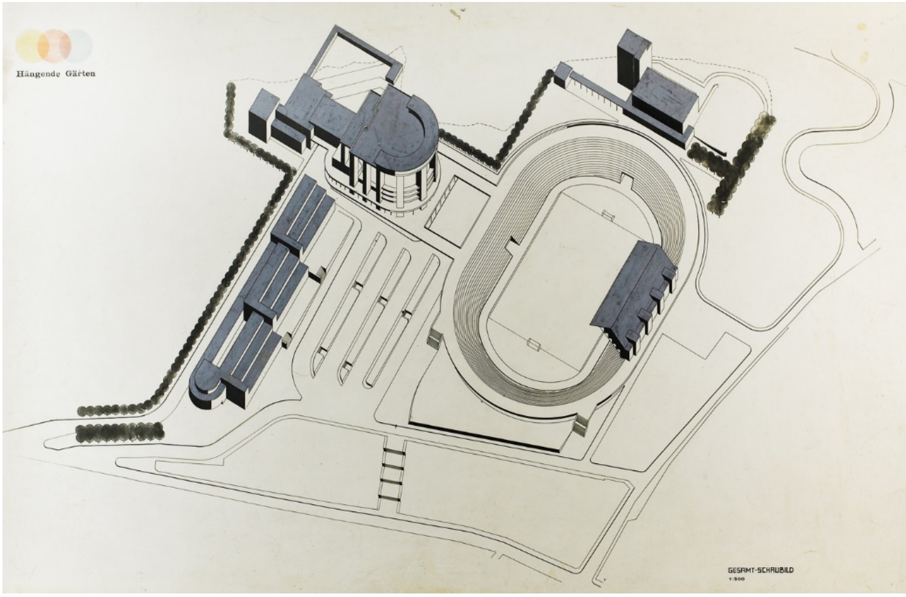

Fig. 2: Walter Gropius: A citycrown for Halle 1927/28, isometry, 1:500, blueprint, ink, washed, gouache (Harvard Art Museums/Busch-Reisinger Museum) © VG Bild+Kunst Bonn 20203 (From drawing to digital model)

2.1 2D Vector Graphics

The site plan and the floor plans, views and sections of the buildings were first converted into 2D vector graphics. On this basis, the first rough 3D data of the outer cubature of the buildings were created. At the same time, the Lehmannsfelsen area was verified based on georeferenced 2D data provided by the city of Halle. The contour line information was transformed into a dense three-dimensional polygon mesh and the adjoining buildings, streets and paths as well as the banks of the Saale were transferred to it and the first 3D model of the existing topography was modelled.

The next step was to merge the information contained in the original drawings on the elevation profile, the building cubatures and the road and path routing from the traffic plan into a coherent open space model and to compare it with the topography model. This confirmed that the special features of the rocky area had already been taken into account in the design.

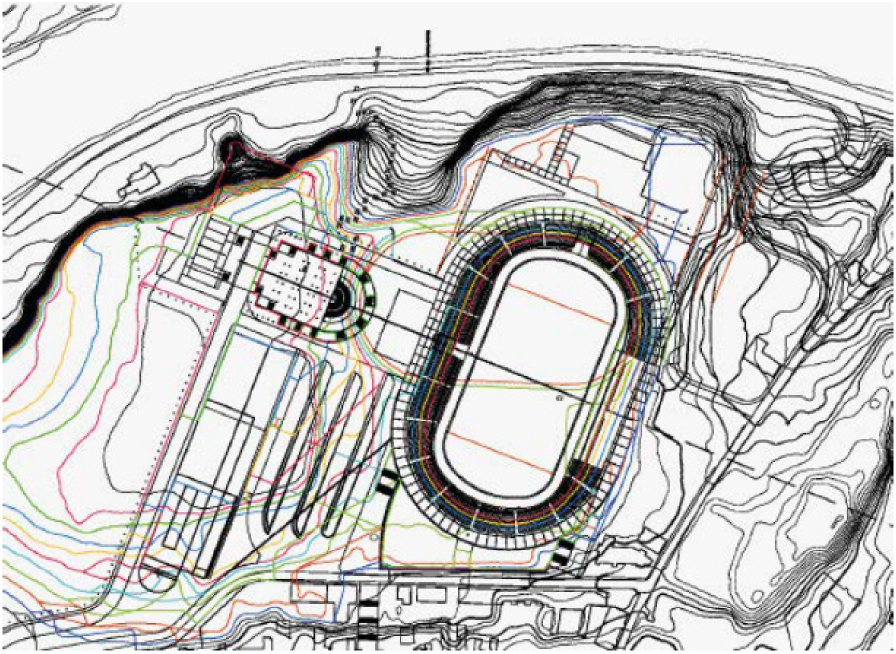

Fig. 3: The Site plan according to original drawing with elevation map, 2008

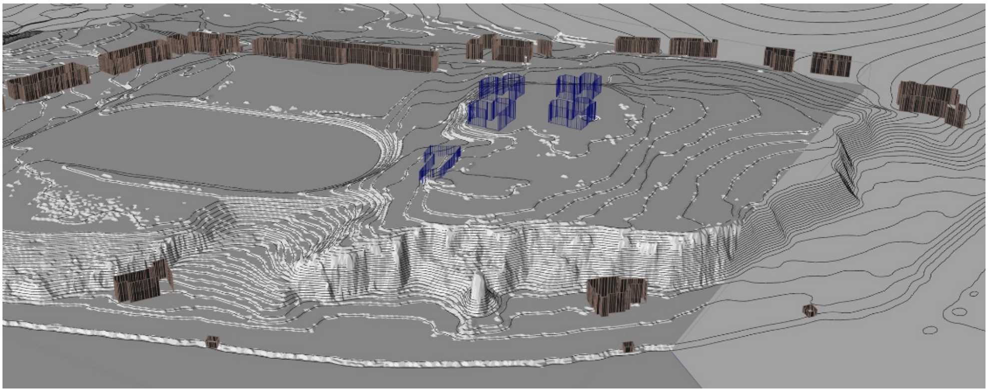

Fig. 4: First 3D model of the existing topography, 2008

The still sketch-like digital model structure was subsequently concretized over several steps to a model character, in which the degree of detail, the color scheme and the materiality are based on scale models. For public presentations, a guided camera flight was created based on the 3D visualization. Starting with the isometric overall view, the guided camera flight shows the overall ensemble and the exterior views of the buildings. This video was shown as part of the exhibition "Eine Stadtkrone für Halle. Walter Gropius in Competition" 2011/12 at the Kunstmuseum Moritzburg Halle and at the Bauhaus Archive in Berlin.

3 Processing of geoscientific data of the Lehmannsfelsen in Halle/Saale

3.1 Georeferencing

Georeferencing is primarily used to compare geographical cartographies (ACKERMANN 2009). It is necessary to compare reliable data from older records and plans with up-to-date and much more accurate representations, correcting older material if necessary. Programs such as Arc-View or Arc-Gis, which meet the high demands for accuracy during a referencing process, are employed for these processes.

3.2 The Terrain Model

In general, a digital terrain model (DTM) or elevation model (DEM) in geography and land surveying does not contain objects on the earth's surface (houses, animals, trees etc.). We used two data sets from grid models for the project "Lehmannsfelsen". The advantage of grid models is the equal division of the measuring points on x- and y-direction. We added the height to every single grid point in the z-direction. Common grid spacings are GDM5 (10m grid), DGM25 (25m grid) and DGM50 (50m grid). The vector format is another possibility, which already contains triangular data with x, y and z coordinates. These coordinates, however, do not necessarily have to lie on a grid.

3.3 Data Review and Reduction (Stripping)

The separation of important and unimportant data takes places while reviewing the geographical data. An elevation file of the project (geographical laser survey in a 1m grid) had a much larger extent than requested (requested was 500×500m, we received 700×800m) and a data format that our CAD software could not read.

In response to the second point, we formatted the data format (here: Gauss-Krüger coordinates) with each point in the form of x,y,z coordinates (example of a coordinate: 4 496 261. 50; 5 707 359. 50; 90. 20) into a point cloud readable by us (x,y,z coordinates in relation to newly defined points for the visualization, example: 0.5; 0.5; 90.2). We formatted all 629 090 points in the batch procedure.

Following, the point cloud be visualized three-dimensionally in the CAD software without having a distance of more than 4496km to the coordinate source in the x-direction. We removed excessive points and reduced the object to a size of 500×500×50m. The advantage of the result was the smaller file size, making the navigation of the entire object much more comfortable. We repeated this process for the model of the Land Survey Office (10m), which was much lower-resolved, but larger in relation to the area of the Lehmannsfelsen.

The resulting point clouds are the starting point for all further conversions and referencing. We, therefore, had to ensure that:

- no descaling takes place, for this purpose, objects are set up in the CAD software (so-called bounding boxes), within which the processed model must remain.
- the units of measurement (mm, cm, km) do not get changed. Each measure of length has determined application-related accuracies.
- all CAD programs within the project reflect the same units of measurement.

- each geometry entering further processing is checked for dimensional accuracy and location (a 10×10×10m cube as reference for size comparisons within the import files).

Another problem is the size of the grid pattern of data from different suppliers. The DGM grid of the data delivery of the City Survey Office was 1m. The DGM grid of the data of the Land Survey Office, however, was 10m. We had to reconcile the data.

3.4 Converting to Polygonal Geometry (Meshing)

When converting to polygonal geometry, a polygon with two triangles is created between 4 points (vertexes). The geometry thus received 17 250 polygons with twice the number of triangles, which later had to be calculated by the graphics. This polygon number is no longer a challenge for modern hardware. However, the number is already too large for 3D online presentations because the terrain takes several seconds or minutes to transmit. Here we had to keep an eye on the target medium and, if necessary, draw attention to the fact that the loading process of such a project takes some time. To keep the amount of data as small as possible we only used the high accuracy of the 1m terrain model in a limited area: in a visual focus of the project. Furthermore, the 10m grid was going to extend to a total size of 800×800m.

Later, a so-called "multiple stitchable terrain engine" can be used within the 3D authoring system to prepare the 3D visualization (ACKERMANN 2009). It allows the user to view the scene while terrain data is still being loaded in the background, and to split terrain information. There are different technical approaches for such systems, the explanation of which will not be included in this text.

3.5 Optimization and Reduction of Data

The optimization of the polygon number of the 3D model makes sense for further processing of the terrain data in the visualization project or the model construction. For this process, we created a combination of the 1m and the 10m grid model. Afterwards, the CAD program (here 3DsMax) corrects polygon errors and reduces the number of polygons of the overall model. An algorithm takes the changes in the height within the predefined terrain section into account. Without having to discard visually vital details, the number of polygons can be up to approximately 10 000.

3.6 Projection of Elevation Lines (Isoline-extraction)

For the Lehmannsfelsen project, we drew the elevation or elevation contour lines at a distance of one meter from sea level, starting from the highest point. How the elevation lines are established is primarily determined by the purpose they are intended to serve.

There are two methods of creating elevation lines. You can either connect all the obvious points of a point cloud on a common plane or project a line structure on the side of the polygonal model in x- or y-direction with the desired height spacing (ACKERMANN 2009). In the first case, the display of the elevation lines is very curved. The disadvantage of this method is that you can only use the elevation data of the point cloud. In the second case, the result is much "softer" due to polygonization, the advantage being the possibility of generating an elevation line at any height. However, a disadvantage is a chance of only obtaining interpolated elevation data between the points. Both methods can be drawn with softer curves later, by rebuilding the geometry and converting the curve types from 1-degree to 3-degree curves.

4 Virtual Reality

Virtual reality (VR) is a real-time three-dimensional simulation of an artificial environment created by using digital techniques. The use of VR-glasses creates a stereoscopic spatial effect, completely decoupling the sense of vision from the real environment. The experience is very immersive, as users act in the digital space through their head and body movements and interact independently with the application. Drawings, images and videos cannot generate such effects. VR-applications enable us to experience non-existent or invisible realities, just like in this exhibition (HANISCH 2021).

Through the interpretation of the two-dimensional design drawing into a three-dimensional model and the use of VR technology, the size and uniqueness of the architectural concepts – in relation to the time of its creation – can be experienced by everyone. The abstract style and representation of the VR-visualization are deliberately not photorealistic to meet the status of a design that has never been realized. The navigation and interaction systems are devised to suit users without any previous VR-experience. Visitors are able to use the application intuitively.

During the period of the exhibition, the VR-model has constantly been refined and enhanced. In addition to many details that were continually amended and revised, there were two significant milestones: The city hall was completely redesigned to make the concert hall visually and interactively tangible. Also, the accompanying program included workshops where participants could discuss and plan ideas for the open space. A few of these designs were subsequently implemented into the VR-model to give an impression of how the architectural ensemble with planting and green space might have looked like. Both enhancements have left a great impression on the visitors[2].

The visual immersion of the VR-scenario really does seduce the user to move in the model. Typically, the radius for physical actions in virtual reality is limited. For the exhibition, however, the designers found a technical solution that allowed the visitors to walk a few steps despite the unavoidable cable connection. Thus they were able to decide themselves how close to walk to the railings of the roof terraces to enjoy the view.

[2] The research project “Stadtkrone.VR” was realized with different programs for modelling and visualization and the program unity3D for the realization of the VR-application. The team chose the VR-headset Samsung Odyssey+ for uncomplicated set-up and cleaning as well as a high image resolution. The headset uses Microsoft’s Mixed Reality Tracking System.

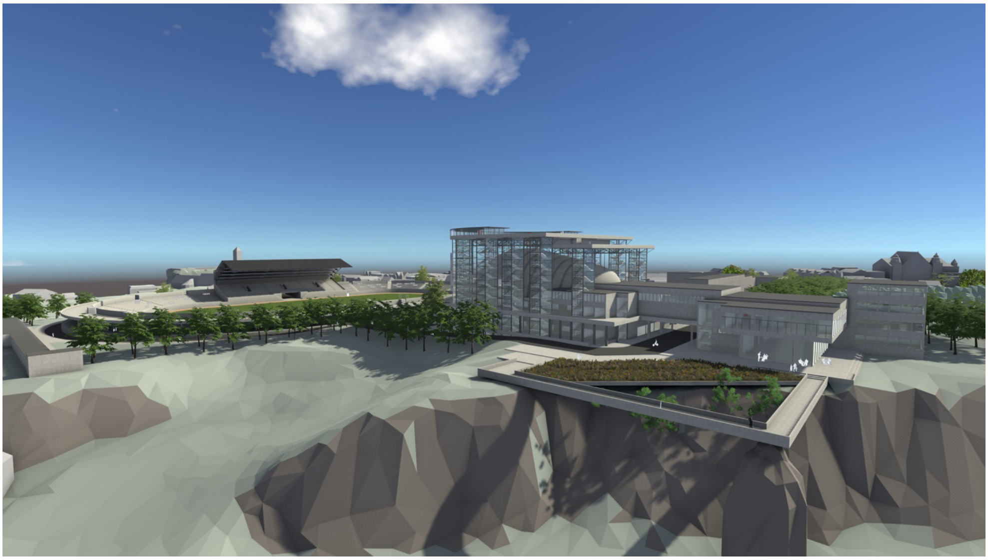

Fig. 5: Virtual view of the "Hanging Gardens – a city crown for Halle", 2019

4.1 Navigation and Interaction

The team developed the navigation and interaction systems under the premise that the vast majority of visitors would be using a virtual reality application for the first time or at best would be beginners in the usage of VR-glasses. Of course, there would also be users who were familiar with the technology. Therefore, the team came up with two different scenarios. Firstly, there is a method for the inexperienced, who would mainly use their head and body movements to interact inside the VR-model. Additionally, there are controllers for those who are already well versed. Since the functionality of the controller is much harder to implement, the focus was mainly on developing an intuitive solution. At this stage, it was of great benefit that experiences and results from previous VR-projects on comparable scenarios already existed. The team developed several concrete concepts and evaluated them.

To be able to change locations quickly and comprehensively on the large area, the use of a miniature map was most promising. The map gives an overview of the site and allows the user to teleport to any location. There are 20 selected points in the form of large pins, which the visitor aims at and activates by aligning their head.

5 Green Space in Virtual Reality – Milestone "Hanging Gardens "

Since the beginning of the project, the team discussed whether to include the hanging gardens in the virtual design. Gropius had renounced the drawing of gardens and landscape in the original plans in order to "not impair the clear assessment of the architectural bodies" (GROPIUS 1928). Thus, a virtual greening could only represent an interpretation, making the subject more vivid to the visitors.

In a workshop, tutors and students sketched ideas and suggestions for possible plants. The challenges were to implement them in the VR-application. While there are a number of plant models for VR-functions, only a few of them are models of real plants. In the search for suitable material, the team involved specialized companies. It soon turned out that their models were only limited suited for VR real-time rendering. Ultimately, most models had to be built manually with a plant generator. However, trees of the same kind never look the same in reality; each grows individually differently. As the viewer would have immediately noticed, there could not be rows of basic models of lime trees (guide models). In consequence, each tree and each bush had to be individualized and positioned separately. At a distance, these tree models work very well, but if the viewer gets closer, it becomes apparent that the image quality is still far from reality.

Due to the numerous trees, bushes, grasses and flowers, the number of polygons in the VR-application increased enormously. Only a few exemplary partial areas were grassed in order to lower the risk of slowing down the refresh rate when turning the head. The team chose lime trees to represent all trees in the design, Gropius also had this tree species planted at the Bauhaus building in Dessau in 1926 (FISCHER-LEONHARDT 2005). As another example for the hanging gardens, the terraces on the rocky edge towards the banks of the river Saale were grassed with wild shrubs. The planting enriches the model, improves the clearness of proportions through more details and conveys the theme of the "hanging gardens" to the visitor.

Fig. 6: Workshop "Hanging Gardens" in November 2019

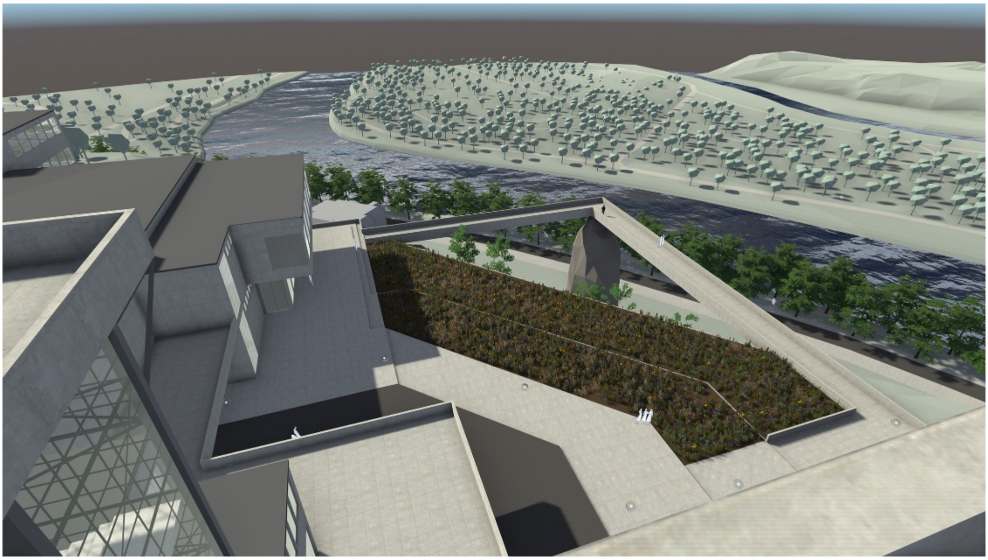

Fig. 7: View from the roof terrace of the 32 meter high town hall to the test area with wild flowers

Fig. 8: Visitor of the AR-guided tour

5.1 Augmented Reality

There already exists technology for visualizing limited areas such as interiors and individual objects. There are numerous applications like smartphones with depth-sensing cameras that enable a true to scale overlay of a piece of furniture in a live-camera image. In contrast, realizing complex scenarios, like the 3D-visualization of the design “Hanging Gardens“ using augmented reality technology in the original area, is a lot harder to accomplish.

There are a number of aspects to be taken into account, such as the exact positioning of the 3D-model, the positioning of the user and the optical characteristics and computing capacity of the devices. On the Lehmansfelsen in Halle, the elevation profile changes considerably, which means that users take a different vertical position every few meters. In addition, the current construction and the stock of trees and bushes limit the possibilities of suitable locations where participants can experience the architectural dimensions and impressive views. Due to the technical feasibility and the specificities of the area, the AR-project was above all an experiment.

After the testing of different prototype solutions and also the use of a mobile VR-station, the team chose the version which enabled on-site guided tours for interested citizens. Each participant received a tablet that visualized the 3D-model in the scope of its intended position. For this, the VR-model was enormously simplified and optimized for the AR-application. Among other things, the team removed components like streets to show the visitor the positioning of the design on the Lehmannsfelsen as comprehensively as possible. The use of high-performance tablets is a compromise because AR-glasses that can display the digital extensions in a high-resolution are not yet available. These mobile devices will then also master an exact positioning determination outdoors.

6 Discussion

The drawings of the original plans are draft drawings and not finalised. Thus, there are areas for which no statements were made in terms of drawings and content, such as the surfaces, materials, stairs and vegetation areas. Within the framework of the research project, an attempt was made to connect all spaces and open spaces and to give them a structure, so interpretations often had to be made. Another topic was the representation of the trees, but Walter Gropius did not specify which type of tree should be used. During the implementation in the VR model, questions arose again and again in this context. One of the main reasons why the small-leaved lime was used as the lead tree in the VR application was the interpretation that Gropius also used this type of tree for the outdoor facilities of the Bauhaus building in Dessau in 1926. The fact that there was already a young avenue of lime trees on the banks of the Saale at the time of the competition was also obvious.

Since in the VR application the user can step right up to the tree trunk and at the same time also look into the distance while turning, the trees had to be modelled both in detail (bark, leaves) and overall (habitus, colour). All trees are interactive in the sense of real time and can thus be interacted with in VR. A digitisation of the trees with the help of image scanning was discarded, as this could not achieve a satisfactory combination of model quality and texturing. Optimal solutions were to be achieved using photogrammetry.

The lime tree used in the VR model was finally modelled, copied and supplemented with interactions. The aim was not to display the models exactly to scale. The decisive factor was that the user should recognise the object to a high degree. The students involved had to be able to visually control the models to not reduce them too much and at the same time have an eye for the textures. The aim was for the photo and the model to look as identical as possible without visual loss.

The figurines in the model are very good for creating proportions. The best proportion reference model is the human being itself. Trees, on the other hand, can be large or small and therefore work only to a limited extent for this purpose.

The minimap has proven to be very beneficial to use. It allows an overview of the entire architectural ensemble in the VR model.

7 Conclusion and Outlook

The exhibition was the result of a year-long research project with the aim of making Walter Gropius' visionary design Hanging Gardens tangible and accessible to visitors and experts using VR and AR technology. This made it possible to reach users who are not normally interested in history, architecture and landscape architecture.

During the project, the following were realised:

- An interactive large-screen projection of the design: self-running 3D visualisation in real time (VR) that could also be individually controlled by visitors via touchscreen.
- Interactive VR stations: walk-through immersive presentation of the design available to visitors in stereo view using VR technology.
- A 3D mini-map and an action space measuring approx. 6 x 6 metres each enabled users among other things, to teleport around the digital site and to move actively to approach the parapets (roof terraces).
- A balloon position also provided an overview.

The user-friendly intuitive interaction model, controlled by the head and body posture, was refined several times and, for alternative use, a controller-supported control for free navigation and teleportation via keyboard inputs were integrated. In the course of the exhibition, the model was detailed and the VR application was expanded. In addition, a new model of the city hall was integrated. After the workshop on the topic of "Hanging Gardens", the greening of the area took place (with mainly specially created models).

The exhibition met with a positive response from visitors. As a result of the visitor statistics, approx. 4000 visitors were counted. Within the framework of the accompanying programme, guided tours for school classes and administration were requested and carried out. The VR application can be borrowed and used for study purposes[3].

[3] stadtkrone-halle.de

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