Virtual and Interactive Reality in Zaha Hadid's Vitra Fire Station

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Abstract

The aim of the research was to analyze the project by Zaha Hadid's Vitra Fire Station in Weil am Rhein using advanced and interactive representation. Built between 1990 and 1993, today the building is a space for temporary exhibitions. We choose it to understand its morphological complexity and to experiment some different interaction systems. To increase the credibility of the virtual environment, we applied seamless textures from photographs samples during the surveys to the 3D model. The Virtual Reality (VR) exploration includes the external context and the building interiors, where we have inserted textual and manual interactions of some works preserved in the exhibition area. We generated two levels of interaction of the scene: with keyboard and VR headset. These two ways allow users to navigate both using hands and walking around.

Keywords
Zaha Hadid, vitra fire station, virtual reality, solid modeling, interactive representation.

doi.org/10.3280/oa-845-c227

Introduction

Virtual Reality is increasingly proving to be a useful tool for the representation, communication and fruition of cultural heritage. Gaming software are the ideal environments for generating it, as they lend themselves well to simulation with real time rendering techniques. These immersive systems allow increasing the value of an architecture – realized, ideal or no longer existing one – going beyond the phases of three-dimensional modeling and production of static output images.

In a virtual exhibition space, it is possible to move and interact with its contents as in the real world: in fact, an observer can visit it, move freely, and take the time necessary to satisfy his personal curiosity about an artwork, an overall vision, or a constructive detail.

To obtain this result, it is necessary to observe an application protocol. A procedure that goes from the acquisition of graphic, photographic and documentary information of the architecture to be reconstructed, to low poly modeling (geometric for architectural or design elements and organic for natural ones), to the generation of specific textures (e.g. albedo, bump, displacement, normal, reflection and procedural maps) and lighting studies (with static or mobile lighting fixtures).

Vitra Fire Station by Zaha Hadid

We identified the VR case study in the Fire Station designed by Zaha Hadid (1950-2016) for the Vitra headquarters in Weil am Rhein.

Vitra is a Swiss company, originally German, founded in the mid-twentieth century whose design production line focuses on furniture for the home, office, and public spaces.

The company is famous for the production and distribution of works by great designers of modernity such as Antonio Citterio, Philippe Starck, Mario Bellini, Alberto Meda, Jean Prouvé and some others.

Willi Fehlbaum founded Vitra's headquarters in 1950 in Weil am Rhein, a German border town located on the eastern bank of the Rhine River near Switzerland and France, not far from Basel (Fig. 1). Here he also built its campus, conceived as a corporate museum and a unique collection of contemporary architecture desired by one of the most prestigious and recognized furniture manufacturers in the world [Kries 2020].

Fig. 1. The Vitra Campus in Weil am Rhein.

Fig. 2. Vitra Fire Station by Zaha Hadid (1990-1993).

Following the great fire in 1981, Vitra decided to have a fire department and commissioned Zaha Hadid to project the fire station (Fig. 2). Today, the building no longer has its original function, and it holds inside events and temporary exhibitions. Nevertheless, despite changing its intended use, today it is still known as a fire station. The building is the first architectural complex designed by Zaha Hadid, and some critics have defined it as a de-constructivist architecture. It is next to production facilities and suggests the effect of an explosion, or a wedge-volume with dynamic shapes that emerges from the ground: an assimilation of lines and planes with a narrow and elongated shape that recalls the neighboring agricultural fields, as if it were an artificial extension of them [De Sessa 1996].
The concrete fragments and ceilings slide over each other creating a straight horizontal profile; this creates a sense of instability that increases when the sloped ceilings slide over each other. Large and glazed cuts lighten the structure of the building, to the point of making one doubt its static nature. The interior of the building is also complex, developed through several partitions that break and tilt, creating a configuration that gradually changes. It consists of storage spaces for fire department tankers, showers and changing rooms, as well as a conference hall and kitchenette. The use of concrete, the lack of decoration and the sharp edges give the visitor a special experience.

Modeling Architecture for VR

Considering the great number of elements and the complexity of some of them, we prepared a working plan for the Vitra Fire Station executable project.
VR modeling must follow some graphical criteria, to ensure processing and visualization in terms of quality and fluidity. Obviously, this is also possible thanks to the high performance of the PC processor and video card.
In this phase, it is necessary to clarify the repercussions that geometric complexities can create for a 3D model. Three-dimensional polygonal modeling works on surfaces organized in mesh composed of polygons based on vertices, edges and faces. This technique allows full control of the creation process, but also offers to modify the 3D object with flexibility and approximate it compared to the real one. The advanced modeling software we used to

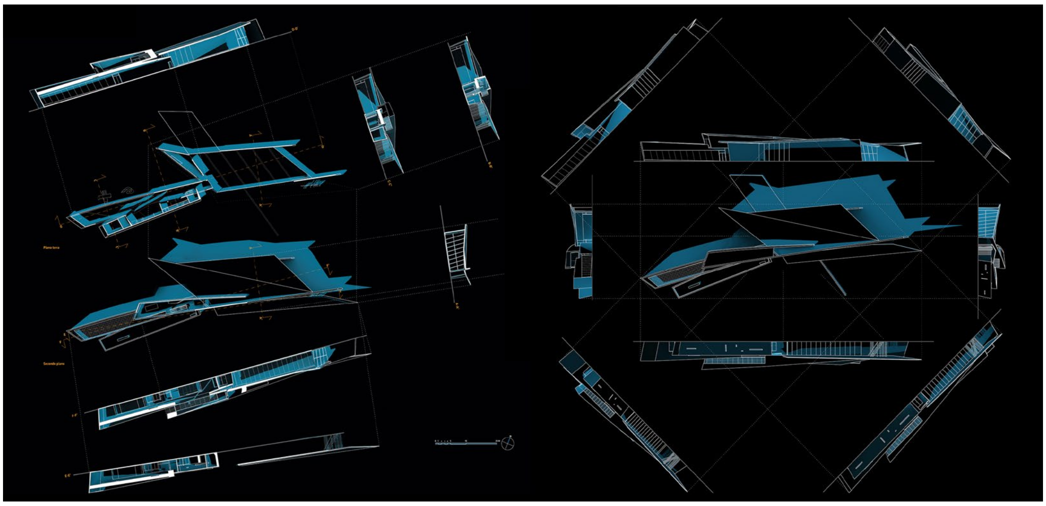

Fig. 3. Zaha Hadid's Vitra Fire Station: a) plans and sections; b) plan and elevations (digital drawings by Mattia Comelli).

create the fire station are the only ones that meet these requirements. We avoided CAD programs because they often produce the "overlaps" faults (surface flickering).
For this case study, we resorted to both geometric modeling, organic modeling, and their hybridization, simplifying the meshes remaining faithful to the real elements' complexity.
In fact, a small number of polygons (low poly modeling) is suitable because it improves performance of the computer, the calculation of shadows is much faster and the visiting experience is fluid, although the quality is lower. However it is little detailed and realistic, unlike high poly modeling. The latter one consists of a large number of polygons also obtained by tessellation but requires high computing capabilities. Surely, low poly modeling is the best one for the development of video games and in the use of VR devices.
However, often the best solution is in the middle (medium poly modeling). It is necessary to find the right compromise between realism and fluidity, even emulating the three-dimensionality with texture layers.
We created the virtual twin of Vitra Fire Station by elaborating and analyzing the drawings by Zaha Hadid (Fig. 3) [Hadid 2004]. However, the only original documents are not enough when you want to emulate a real environment. The visit to Weil am Rhein was fundamental to collect all the photographic material necessary to determine the correct geometry of the architecture and to highlight some differences between project and realization, but also for the reproduction of the real textures. In addition, to enhance the realism in the virtual environment, we also modeled a great part of the Vitra Campus, such as the Vitra Schaudepot by Herzog & de Meuron or the Factory Building by Alvaro Siza.
The survey was also essential to create furniture and design objects exposed inside, such as the *Mesa Table* (Fig. 4a). Thanks to the photographs and dimensional information stored on the website, we reconstructed the objects and applied chamfer modifiers (medium poly) to them to emulate plasticity.

Texturing and Lighting Architecture for VR

In addition to the 3D model, maps and UV textures also make up a VR scene.
The material yield in the graphics engine is an important component. We apply it to the mesh to control the visual appearance and calculate the interaction of light in a scene.
We applied an unwrap modifier to each 3D element. It is fundamental because it allows us to assign more channels to the same object. In the gaming environment, this guarantees a good shader, which must be composed of different image textures, mathematical expressions, and intrinsic material benchmarks. In fact, in addition to the chromatic data, a material has surface parameters such as roughness, opacity or reflection. If we aim for high realism through texturing, we need to structure definable visual scripting nodes in the material editor.

Thanks to pictures appropriately taken during the survey and the image processing software, we prepared the seamless textures of the fire station: floor and wall coverings (external concrete panels, bricks, tiles) but also the fabrics and materials of chairs and tables. We proportioned the real-scale reproducible maps and associated each material with different surface characteristics.
The lighting of the scene also plays a relevant role. We have also assigned an unwrap modifier to properly illuminate and structure each 3D entity (fig. 4b). This process allows us to convert the surface of a solid object into two-dimensional elements. The mesh faces are broken and placed on a Cartesian plane without overlapping. A large area occupied by this subdivision ensures a better quality of shadows.
The UV map serves the rendering engine. Depending on the lighting, it calculates the shadow and saves it on a secondary channel, in addition to the map itself. This operation avoids the further real-time processing of object shadows because they are preloaded previously.
The lighting takes place with an algorithm of light mass applied to the objects of the scene.
In the game engine, we find three kinds of lights: static, fixed and dynamic. This distinction is necessary because it greatly affects the way light works and its impact on calculation. Depending on the type chosen and adopted, there are different compromises between quality, performance and changeability of the scene. Static lights use only light maps, and we calculate their shadows during processing, before starting the gameplay.

Rendering

For VR, gaming software uses the Graphics-Processing Unit (GPU) to render faster but with lower quality than the Central Processing Unit (CPU).
The classic real-time 3D engine technique is Forward Rendering, instead gaming software uses Deferred Rendering. They differ in the processing of geometries and in the calculation of light. Once the scene is set, during the calculation phase the software creates a list of lights illuminating the object.
In Forward Rendering, the process is linear but disadvantageous, because depending on the scene framed, the calculation of rendering will have to consider every light in the scene for each geometric object.
On the contrary, Deferred Rendering allows treating lighting only in the space visualized in the screen. It calculates only what you see, going to temporarily leave out information that is not directly present in the field of view. This method considers fewer polygons and is therefore faster in terms of calculation.
Forward Rendering calculates the light for all the geometries, in Deferred one the calculation regards only the directly visible elements.

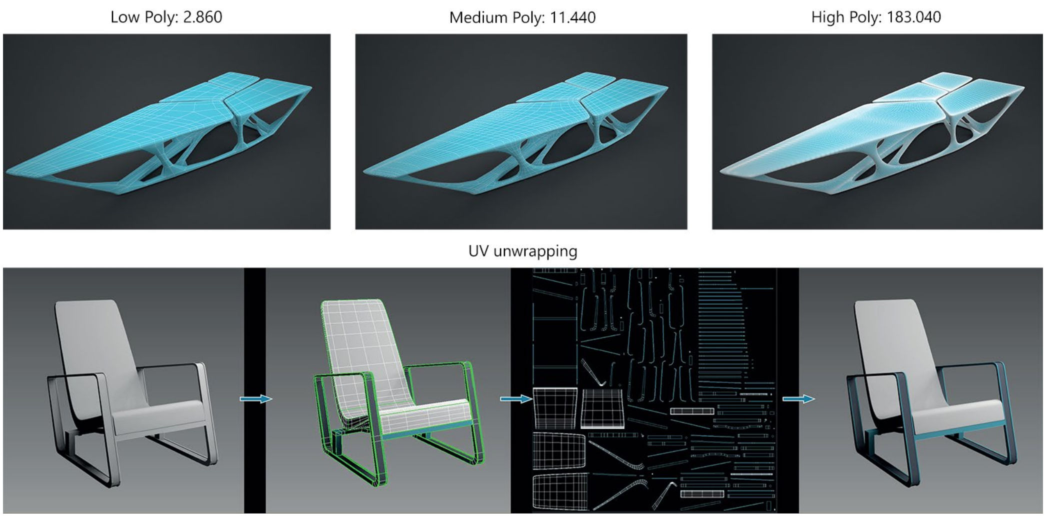

Fig. 4. a) Comparison between low, medium and high poly models applied to the *Mesa Table* designed by Zaha Hadid; b) UV unwrapping process (elaborations by Mattia Comelli).

Fig. 5. Frames taken from the virtual twin of Zaha Hadid's Vitra Fire Station: a) exterior and context; b) first floor meeting room; c) ground floor and *Mesa Table*; d) Interactive-exhibition hall with design chairs (graphic elaborations by Mattia Comelli).

However, the Deferred Rendering presents some criticalities. The first issue is the calculation of geometries, because processing only what is displayed by the camera some geometries may get lost or distort the final effect. It also presents problems in the representation of transparent and reflective objects and in the accuracy of the calculation in post-production. Finally, in the display you notice the aliasing effect, a phenomenon in which oblique or curved lines have a scaled appearance.

Interactions and Virtual Visit

For an effective immersive experience, it is important to allow maximum freedom of movement and implement the system with the programming of interactions.
The virtual visit starts outside the building (Fig. 5a), in front of the entrance with the glass door. The navigation area has been set within two base stations at 3x3 m: in this space the user moves with direct movement, otherwise he can set a new approach through the trackpad, activating a trajectory for the teleportation system.
The virtual area of the Vitra campus containing the fire station covers about 850 sq. m. Inside, all the rooms on the ground and on the first floor can be fully explored in the virtual tour by the user (Fig. 5b-c-d).
Like materials and lighting, collisions and interactions are set and managed in gaming software. Collisions are important constraints for visiting VR environments. In fact, you must set up blocks so as not to go beyond the walls and allow you to travel through spaces. Collisions are the basis of interactions, and we can solve them through C++ or blueprint programming. Specifically, for this study we used the blueprint interface based on node structuring.
In addition to the physical constraints of walls, ceilings, staircase and terrace, we have added several levels of automatic and manual interaction. Automatic interactions relate to the movement of cars on nearby streets or the simulation of the breeze on vegetation. We find instead between direct interaction: the opening of the doors, textual and manual information activated approaching them or with trackpads.
In the exhibition room, approaching with the joysticks to the design chairs will appear short descriptive texts of the artworks, which report title, designer and year of implementation. On the first floor, in the meeting room, the visitor is even more involved in the VR scene because he can grab a toy in the form of an elephant, hold it in his hands simulated by trackpads and place it wherever he wants (Fig. 6).

Conclusions

Current Virtual Reality developments show that the systems now available are integrating and perfecting the three types of application – passive, exploratory and interactive – that until recently were distinct from each other or partially implemented [Aukstakalnis, Blatner 1992; Muscott, Gifford 1994].
These new multimedia technologies of fruition, in fact, allow to activate in a dynamic and interactive way the exchange between current events and virtuality, making the visitor an active participant of the digital-virtual scene proposed.
There are many strengths that these systems can offer in the fields of education, museums, and tourism [Özdemir 2021], as the creation of specific scenarios – related to the world of architecture, urbanism archeology, painting, history, design, etc. – can overcome the passivity of content transmission, increase knowledge by offering opportunities for multi-sensory and emotional involvement in the logic of "learning by doing" thanks to gamification strategies.
Through this VR project presented in this research, we can better understand and visit a complex architecture such as Zaha Hadid's one, a famous international building not always easily accessible to everyone.
The project for Vitra Fire Station is very useful to understand limits, potential, future developments and implementations for the creation of other executables.
By taking advantage of this complex building, we were able to understand and perfect the interaction system.
The results of this elaboration, therefore, allow us to proceed in optimal way in the successive investigations that regard the simulation in real time of an architecture of a certain morphological complexity inserted in an urban context, such as the Vitra Campus.
Currently our research is proceeding with new architectural projects and testing new hardware and software devices to exploit these systems in the dissemination and knowledge of cultural heritage.

Fig. 6. Textual and manual direct interactions in the VR model of Zaha Hadid's Vitra Fire Station.

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