Producing Virtual Walkthroughs from Architectural Models: a case study of the New University Building

Rowan de Graaf
E-mail: Rowandegraaf@gmail.com
College ID: 6059031

June 17, 2015

Supervisor(s): dr. R.G. Belleman (UvA)
Signed:
Abstract

This thesis presents a workflow for the production of a Virtual Walkthrough from a given architectural design. We identify a number of conversion and optimization steps needed to produce a model suitable for a Virtual Walkthrough from a raw architectural data source. These steps are connected in a workflow that iteratively optimizes the model until a level of performance is attained. The workflow is evaluated in a case study of the New University building, in the form of a Virtual Walkthrough using the Oculus Rift head-mounted display. The constructed model closely resembles artistic impressions provided by the architects, while maintaining high performance, resulting in a smooth and immersive user experience.
# Contents

1 Introduction ................................. 5
   1.1 Overview of this thesis .................. 6

2 Background & Related work ................. 7
   2.1 Origin .................................. 7
       2.1.1 Virtual Walkthrough ............... 7
   2.2 Virtual Reality ......................... 7
   2.3 Applications ............................ 8
       2.3.1 General ............................ 8
       2.3.2 Architectural ....................... 9
       2.3.3 Comparable research with this thesis .......... 9
   2.4 Technology ............................. 9
       2.4.1 Software ........................... 9
       2.4.2 Architectural data sources .......... 10
       2.4.3 Interaction with Virtual Reality ....... 10
       2.4.4 Movement in Virtual Reality ........ 10
       2.4.5 Vision in Virtual Reality .......... 11

3 Design ..................................... 13
   3.1 Context ................................ 13
   3.2 Components ............................. 13

4 Case Study .................................. 17
   4.1 The NU Project .......................... 17
   4.2 Technical goals ......................... 18

5 Evaluation .................................. 19
   5.1 Optimize modifier ....................... 19
   5.2 Weld modifier ........................... 20
   5.3 Model finalization & Performance ....... 20
   5.4 Software product ....................... 21
   5.5 Summary of results ..................... 21
With today’s increasing interest in Virtual Reality a wide variety of applications come to mind. VR is used for training in the army [28], entertainment purposes for flights [9] and exploration of areas [16]. We explore the use of a Virtual Walkthrough (VW) to explore architectural designs. A VW offers an immersive experience that improves spatial awareness with respect to a two-dimensional artistic impression [21]. We identify at least the following categories of simulations that can be enhanced by application of a VW:

- **Architectural**
  The perspective offered by a VW helps in the discovery of design flaws. For example, an inconveniently positioned pillar is more easily discovered when bumping into it during a simulation, than when looking at a blueprint.

- **Positioning**
  The positioning of a building combined with its unique design might cause problems. If solar simulations would have been used prior to building London’s “Walkie-Talkie” [19] they would have noticed that the unique form of the building caused the incoming sun rays to be bundled and projected down on the street on one spot.

- **Interior filling**
  Complex spaces within buildings can be filled by computer algorithms. This way the wishes of the owner produce a best-fit for the interior design (desk placement). Not only can this be used for the spacial interior design but also for example the placement of employees within a building [7].

Before a Virtual Walkthrough of a building can be developed, a suitable computational model of the architecture needs to be available. The source of choice for any architectural project will be the architect. The format and complexity of the source data supplied by architects differ from those required by current software that is used to create Virtual Walkthroughs. In this work, we present a workflow which enables us to bridge this gap. In the process, we answer the following question:

- Are data sources produced by architects suitable for “virtual walkthrough” simulations, and if so; what is necessary to produce such a simulation?

As a test case, this thesis takes the “New University” (NU) building, the proposed new home of the Information Sciences departments of UvA and VU, the construction of which has started in 2014 and will be finished in 2018.
1.1 Overview of this thesis

This thesis finds its foundation in the workflow of a certain process, a recipe it might even be called. Below is the structure of this thesis.

- Chapter 2 provides background information regarding Virtual Walkthroughs, Virtual Reality and its technology. Furthermore related work concerning these two fields is discussed.
- Chapter 3 provides the design upon which the workflow is constructed.
- Chapter 4 provides a case study and the technical goals imposed on this project.
- Chapter 5 provides an evaluation of the results after application of the workflow on the case study.
- Chapter 6 provides a discussion in which other solutions are explored and a proposal for future work.
- Chapter 7 provides the conclusion of this thesis which consists of a summary, the proposed research question and further application of this thesis’s work.
- Finally, Appendix A provides a comparison of the evaluated results and its corresponding artistic impressions.
This section is based on the explanation of the cornerstones upon which this thesis is build, that of Virtual reality and Virtual walkthroughs.

2.1 Origin

2.1.1 Virtual Walkthrough

A virtual walkthrough (VW) is the term for exploring a virtual environment (VE). The VW’s are realized with the use of Virtual Reality (VR) environments. In a VW the user is equipped with a head-mounted display (HMD) and/or peripheral devices which can control movement. In this setup the user’s sense of vision is “fooled” by receiving stimuli from the HMD. A whole new reality is created and the user is emerged in the VE.

The first use of a VW that we know of is by I. Sutherland in 1968[26], who was able to explore a wireframe room using an HMD. The first public application of a VW was a 3D reconstruction of the Dudley Castle in England as it was in 1550.[16]

With the use of VWs users can experience areas which they could previously not (think of areas which require travelling). Not only areas which already exist in the real world but also areas which do not even exist yet. We focus on the latter, in the light of our focus on architectural design.

2.2 Virtual Reality

A Virtual Walkthrough is an application of Virtual Reality (VR). VR replicates an environment that simulates a physical presence in either the real world or one self designed. Within this world senses such as touch, vision and sound can be emulated for the user, based on the VE. The term “VR”, coined by J. Lanier in 1987 was interchangeably used with the term “VE”. It was not until after the article “Defining Virtual Reality: Dimensions Determining Telepresence” written by J. Steuer[24] before VR and VE got their own definitions and applications of one could properly be named.

VR found its origin in the research field. The first application of VR with the HMD developed by I. Sutherland was one which had to be supported by the ceiling. The HMD was ahead of its time and the application of VR was limited by the technology on which it was used. It was not until 1991 in which the first construction of the Cave Automatic Virtual Environment (CAVE) was finished at the Electronic Visualization Laboratory. The CAVE is a multi-person, room-sized, high-resolution 3D video and audio environment.[10]
Developments in the area of VR have taken a big leap in the past years making VR more accessible to the masses. The Oculus Rift Development Kit 1 in 2012 started a rivalry which led to the development of multiple HMD’s. Computers are now capable of running sophisticated VR simulations and the hardware has become so small that a HMD can now be worn without any supportive structures. Therefore, making them popular with the public.

2.3 Applications

2.3.1 General

VR - What’s Real About Virtual Reality?

F. Brooks wrote an article[6] reporting on the real progress of VR. By many sources it was claimed that VR “Almost worked” but in practice it seemed that a lot of the applications worked barely. The most challenging part concerning the use of VR was the end-to-end latency of the systems used in the simulations. Immersion in VR takes a great hit due to this end-to-end latency cause stimuli needs to be on point and expected by the brain. Some of the big challenges back in 1994 were the rendering of models with more than 1M polygons and choosing which display suited the application best: HMD, Panorama, Cave.

VW - Archaeology, museums and virtual reality

L. Pujol wrote an article[18] which explains the use of VR and VW based on archaeology and cultural origin. The article further discusses whether VR can be used as a proper representation of archaeological finds. It is concluded that VWs based on archaeological finds are sophisticated enough to be used for archaeological purposes as well as cultural applications in museums.
2.3.2 Architectural

VR - From CAD to virtual reality: modelling approaches, data exchange and interactive 3D building design tools

The research done by A. Thorpe et al in this paper [13] is based on the connection of architectural design and VR. It compares the use of Virtual Reality Modeling Language (VRML) [30] within CAD to the manual method in 3D Studio VIZ [25]. Concluded within the paper is that straight conversion of CAD models to VRML gives inconsistent results and a more manual approach using 3D Studio Viz is favorable.


This [12] case study was based on mapping the architectural structure a specific cultural site in this case “The Small Wild Goose Pagoda” in the Tang Dynasty. This study presents a method in which laser scanning is combined with photography. This method proves to be effective in creating 3D models based of existing constructions. These scanned constructions are later used for application within VWs.

2.3.3 Comparable research with this thesis

VR - Virtual Office Walkthrough Using a 3D Game Engine

The research done in this paper is a workflow in which they create a model from 2D drawings in a gaming engine [22]. Though due to the technical limits set by that time the result produced was not satisfactory. The game engine used Unreal Engine 2 and has a limit of 30 FPS. Since a smooth VR experience requires at least 60 FPS (30 FPS per eye) the workflow described in this paper is less suitable for the usage in VR.

VR/VW - Users’ evaluation of a virtual reality architectural model compared with the experience of the completed building

This paper described the architectural use of VR models to inform their future employees [31]. Results of the paper pointed out that VR can be used to give an accurate example of a yet-to-be-built construction.

2.4 Technology

2.4.1 Software

Whenever we separate linear explorables 360 degree pictures from actual 3D interactive models a couple of software packages come to mind. Model-and-walkthrough software packages such as Sketchup [23], Rhino [20], allows the user to create 3D models and have a VW through them. Even HMD’s can be used in some of these software packages.

More complex 3D interactive model simulations can be created in gaming engines such as Unreal Engine 4 and Unity. Mostly these gaming engines are used in combination with 3D modelling software such as 3DS MAX [8], Rhino, Blender [4] and others. The use of a gaming engine within this aspect allows the user to actually partake in a VW since the 3D model software itself does not support this.
2.4.2 Architectural data sources

Architects use software which is specifically developed for designing buildings. Black spectacles, home of e-learning courses regarding architecture and design\cite{27} conducted research over 900 job opportunities for architectural jobs within the top 50 companies active in architecture. The results conclude that from the 900 jobs 71% require knowledge of Revit\cite{11}, 50% of AUTOCAD\cite{2} and 35% of Sketchup. None of these programs support out of the box interactive 3D model production.

Models produced by these programs contain all information about a building whether its the thermal packaging or the double glass windows. All this information is not needed for example with a graphical representation of a building. Therefore the data supplied by architects, whether it be a 2D drawing or a special architectural design format, it is not suitable for generating an out of the box 3D computer model.

2.4.3 Interaction with Virtual Reality

The Leap motion controller

The Leap motion\cite{14} is a small device which is able to detect hand movement in a small specific area. Interaction with the leap does have downsides while in a VW due to the small area in which the Leap is used. Therefore only specific simulations which keep the real world placement of the leap in mind are able to benefit from its features.

![Leap motion device](image)

Figure 2.2: In the left picture displayed is the original use case for the Leap. The right picture presents a modification to the HMD which makes use of the Leap in VWs more suitable.

2.4.4 Movement in Virtual Reality

Virtuix Omni

When a VW is conducted, motion tracking can be used to simulate movement in the VW. Using this way of tracking means the explorable area in VW needs to be smaller or equal to the size of the real world space. This limits the use of exploration in VW.

This is the problem for which the Virtuix Omni\cite{29} was developed as a solution. This omnidirectional treadmill makes 360 degree movement possible without changing your own position in the real world.
2.4.5 Vision in Virtual Reality

Oculus Rift

The Oculus Rift is an HMD which creates a perspective view for each eye, creating a stereoscopic 3D image. The human eye is able of distinguishing 30FPS. It is important that no “lag” occurs (smearing and/or stuttering of graphical image), this creates an unpleasant experience for the end-user. Therefore the simulation created for an Oculus Rift needs to run at at least 60+ FPS.

CAVE

The CAVE can be used for a wide variety of applications, nevertheless it is best used for exploration of small areas or the necessity of studying a certain object while being able to walk around it. Within the CAVE graphics are projected in stereo onto three walls and the floor, and viewed with active stereo glasses equipped with a location sensor. As the user moves within the display boundaries, the correct perspective is displayed in real-time to achieve a fully immersive experience.
3.1 Context

The workflow created in this thesis is based on the source data supplied by architects and the hardware available for this research. Supplied by the University of Amsterdam is an Oculus Rift, this is used as the HMD for the VWs. Movement and other interaction is done by the use of an Xbox 360 Controller. Using the Oculus Rift imposes certain performance requirements. Performance is impacted by the polygon/vertex count of a model and the environment created for the VW. The game engines which support the Oculus Rift are Unreal Engine 4 (UE4) and Unity. Due to the open source origin of UE4 and its free licensing UE4 is used for this project. This choice does not affect the designed workflow since the best supported import format of both programs is FBX. The input used for this workflow is that of the Revit format, due to its popularity within the architecture and design sector as pointed out in Section 2.4.2. Revit is used either to design, or join 2D designs of a building. The output of the workflow will be that of the FBX format since it is broadly supported by both game engines.

3.2 Components

Generating a 3D model straight from a Revit format results in a complex computational model. The geometric shapes shown in this 3D-model are very realistic. This is due to the level of detail needed in the construction of a building. Importing these models directly into a gaming engine results in a poor performance.

Since the direct conversion of the Revit format results in poor performance, the model needs to be optimized. Optimization of the model is done by 3D modelling software. For this purpose a variety of programs can be used such as 3DSMAX, Rhino and Blender. We use 3DSMAX. The purpose of this step is to reduce the amount of detail in the 3D model generated by Revit. This is achieved by modifying the polygon/vertex structure of the model, effectively reducing the complexity of the model with the use of the weld modifier. Especially rounded objects benefit from this step due to their creation by approximating \( \pi \) (see Figure 3.1).

Exporting the optimized model to FBX generates an acceptable file for the gaming engine. All individual items which are found in the FBX file are imported as single meshes. Big architectural buildings could easily contain two million individual items, therefore two million individual meshes would be created. No game engine is capable of contain that amount of meshes. For this reason the meshes need to be grouped, based on either type, manufacturer or material. The Collada format is based on creating meshes based on materials. Therefore an export in Collada format from Revit is required.
Changing the Revit export format from FBX to Collada (DAE) causes the objects in the model to be grouped by material. The standard for 3DSMAX is FBX. Support for importing the Collada format within the Autodesk series ( Revit and 3DSMAX ) is less than ideal. Importing of Collada files can only be done by chunks of 20MB each import. This way for a base model of 400MB to be exported, you would have to cut it up in 20 pieces. Therefore conversion of the Collada format is needed. This conversion is done with the help of FBX SDK Converter. The FBX SDK Converter accepts multiple 3D formats such as OBJ, DXF, 3DS and DAE all of which can be converted to FBX. With it an FBX format is created from the Collada Revit export.

After importing the optimized FBX model into the gaming engine, the model can be textured. As soon as the texturing is complete additional environmental lighting can be added to the scene. After this step performance of the created VW is tested. In case of poor performance, either the scene needs to be edited or further reduction of the optimized model its complexity is required.

The steps taken above are visualized in Figure 3.2. The workflow described is based on software used for these types of projects.

The workflow constructed is applicable to a variety of buildings. If a more detailed VW is required the user chooses for an Revit FBX export. Choosing to do so opens the possibility to...
use static lighting. Static lighting in big constructions is not possible due the unwrapping stage in the gaming engine.

An object’s UV channel stored the texture properties. Using static lighting enables the user to add complex lighting sources to his environment. The use of complex light sources and its effects (shadows). After “calculating” the effect of the light sources on its environment the information can be stored into the texture. This way no computation is done regarding lighting during the simulation. The storing of these textures is done in 2D images. Exporting the file to a Collada format creates big meshes which contain all items with the same material. These big meshes can not be unwrapped into 2D images. Therefore, static lighting is not possible in some cases.
4.1 The NU Project

The NU is the name of the proposed new housing of the information science departments of the Vrije Universiteit Amsterdam and the Universiteit van Amsterdam. The building involves a thirteen stories high building with unique features such as:

- Seven floors of open housing.
- Multiple floor college rooms.
- Stores on the bottom floor.
- 80% glass exterior.
- Unedited 3D model has 17 million polygons and 15 million vertices.

Since the NU is being built as a shell only without any designation for the areas, it is up to the VU and the UvA to fill in the areas respectively to the needs of the employees.

For this project it is not only important that the architects and designers know what the building will look like, but also the new employees. Therefore a more interactive solution was wished for. A 3D model needs to be created, based on the architectural sources. After this 3D model is created, it will be determined if a VW helps with the development of a building, and whether data sources supplied by architects are suitable for projects such as these.

![Image](image1)

(a) Interior view.  
(b) Exterior view.

Figure 4.1: Artistic impression of the NUVU Project. [15]
4.2 Technical goals

For this experiment to be a success a set of technical goals have been determined:

**Create an interactive model of the NU building.**
To be able to do a VW in VR we need a 3D model of the building. The software used by the architects (Revit, Autocad, Sketchup) do not have a built in feature to generate a VW suitable interactive model.

**The interactive model must be viewable with an Oculus Rift.**
The Oculus Rift is used as HMD for the VR part of this project. Therefore, we need to use software which is able to render to an Oculus Rift.

**The interactive model must run at at least 60 frames per second (FPS).**
Since the human eye is able to perceive 30FPS per eye and the Oculus Rift generates a stereoscopic image the total framerate of the final simulation need to be at least 60FPS. If this threshold is not met, smearing of the graphical image could create a less optimal experience for the user. Important is that a resulting model with a FPS of lower than 60FPS could still be an accepted model since only the experience suffers from this technological limit.

**All thirteen floors need to be implemented in the model.**
With regards to the research question whether the VW helps the development of a building, it is important that the VW resembles the same experience as the real building. For this reason alone it is important that all thirteen floors are properly displayed at once.

**The model needs to look realistic, textures are a necessity.**
The VW will be used to instruct employees about the building therefore it needs to look realistic. Since VWs are not generally used and neither are normal 3D models, normal grey blocks reduce the perception of the end-user due to lack of definition. Using textures makes perception easier and more realistic to the end-user.

**The model must be realized by a definable workflow.**
Every object in reality can be modeled into a 3D model by hand. The workflow described in this thesis is one that needs to be applicable on architectural drawings in general. Therefore, a small portion of the process may be done by hand but the workflow needs to be focused on usage on an autonomic scale.
CHAPTER 5

Evaluation

5.1 Optimize modifier

As for all interactive 3D models which need high performance less polygons is better. Polygons impact the amount of FPS. To reduce the amount of polygons and vertices the optimize modifier can be used. The algorithm is based on the angle in which faces are connected as well as open edges (edges that bound only one face). Parameters for both the angle of the edge and face can be given to reduce the complexity of the model. Use of the optimize modifier is demonstrated in Figure 5.1.

Figure 5.1: Using the optimize modifier effectively reduces polygon count with barely any loss of graphical detail.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Original Model</th>
<th>Optimized Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polygons</td>
<td>12.0</td>
<td>5.9 (49.2%)</td>
</tr>
<tr>
<td>Vertices</td>
<td>13.7</td>
<td>7.8 (56.9%)</td>
</tr>
</tbody>
</table>

Figure 5.2: Optimization modifier with faceangle = 5 and edges = 2. Complexity of the model is reduces with almost 50%.

Figure 5.3 shows the comparison of the interior of the optimized building. Shown is a graphical glitch caused by the optimize modifier. For this reason the evaluation done on the 3D model is done by human interaction and not by computer, since the computer cannot be taught to differ these errors in structural modelling. Optimal settings could be found for the optimize modifier.
5.2 Weld modifier

3DSMAX’s Weld modifier merges a specified amount of vertices into one vertex if the distance between those vertices are lower than a specified threshold. The goal is to find values for these parameters such that the complexity of the model is reduced as much as possible, while still maintaining a certain level of graphical quality. Due to differences in shape, some objects allow for a higher level of optimization than others. If the same parameters are used for the whole model, optimization is restricted to the level of the least optimizable object (i.e. the object that cannot be optimized further without losing an unacceptable level of graphical quality). Table 5.4 shows that a more fine-grained selection of parameters yields a substantially higher reduction in complexity.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Original Model</th>
<th>Uniform parameters</th>
<th>Fine-grained parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polygons (M)</td>
<td>12.0</td>
<td>11.9 (99.2%)</td>
<td>3.8 (31.7%)</td>
</tr>
<tr>
<td>Vertices (M)</td>
<td>13.7</td>
<td>10.6 (77.4%)</td>
<td>5.2 (37.9%)</td>
</tr>
</tbody>
</table>

Figure 5.4: Number of polygons and vertices before and after application of the weld modifier. Uniform parameters yield only a 0.8% reduction as opposed to 68.3% when using a fine-grained approach.

5.3 Model finalization & Performance

After finding the most suitable model for creating a VE, lighting and textures are applied within UE4. Applying the textures to the meshes is done by hands since the original model did not have any textures. With respect to the realistic feeling of the VW textures have been chosen which are comparable to the artistic impression supplied by the architectural bureau.

Since static lighting can not be used, a dynamic skylight is introduced. Its sole purpose is the ambient lighting of all objects since there is no shadow or interaction with the light itself.

The VW created seems one of additional value. The artistic impression by the architectural bureau consist of 8 pictures and a small animation real of the central two floors. With this VW interested parties can experience the building. Not only can this VW be used to look at concepts which are already in place for when the project is being built, but also to create new ones.
The comparison results between the product created with the use of the workflow applied to the case study and its artistic interpretation can be found in Appendix A.

The VW was tested on a machine with an Intel i7 2600K processor and an ATI R9 290X graphics card, running at 195-215 FPS. Although this can be considered a high-end gaming system, these numbers indicate that a medium-end desktop computer will likely be able to attain 60FPS. We also tested the VW on a laptop with an Intel i7-4750HQ processor and an Intel Iris Pro Graphics 5200 graphics card, running at 28-35 FPS. While this is too low for use with the Oculus Rift, one can not expect a complex VW such as this to run at full performance on a laptop. Hereby we conclude that the technical goal of 60FPS was met.

5.4 Software product

For this project the following programs were used:

**Revit 2016**
- Revit is used for opening the source file, selecting what parts of the building to be exported.
  - **Source:** 12274-NU.VU-20140901.rvt
  - **Produced:** NUVU-GeometryMax-Full.DAE

**FBX SDK Converter 2013**
- The converter is used for transforming the DAE file to FBX.
  - **Source:** NUVU-GeometryMax-Full.DAE
  - **Produced:** NUVU-GeometryMax-Full.FBX

**3DSMAX 2016**
- 3DSMax is used to optimize the FBX model efficiently reducing its amount of polygons.
  - **Source:** NUVU-GeometryMax-Full.FBX
  - **Produced:** NUVU-GeometryMax-Full-Weld.FBX

**Unreal Engine 4 - v4.8**
- The Unreal engine is used for creation of the virtual environment. This includes mesh placement, environmental lighting and texturing.
  - **Source:** NUVU-GeometryMax-Full.FBX
  - **Produced:** NUVU Project (Directory) 920MB in size.

5.5 Summary of results

After application of the workflow onto the source file of the NU Project a VW is created. The VW created satisfies all technological goals imposed by the project. The visual representation of the model required some manual labor. This due to no textures being present (except for clay colours) in the source model. Application of custom textures took 2 hours, including lighting. With these results it is concluded that the workflow works for an architectural structure of great size.
CHAPTER 6

Discussion & Future work

6.1 Discussion

Creating a VW from a building is not a linear task. Even though a VW can be created from certain data sources produced by architects a lot of optimization needs to be done. The resulting VW created in the process can be used to create a spatial image for the user, mostly because artistic impressions do not cover every single aspect of a building.

Certain optimizations by UE4 could not be used due to the way the data of the 3D model was organized. Creating an FBX format from the Revit file instead of a DAE file format would have taken a longer time to texture. If a 3D model which was already textured could have been exported from Revit the time spent texturing would have been lower. With these small meshes a feature called culling could have been used. Culling prevents UE4 of rendering specified sized of objects whenever they are to far from the camera. In contrary to our resulting VW where everything is rendered. The reason why culling does not work in the thesis specified workflow is due to the usage of the DAE format. The DAE format produces large meshes which contain all the objects with the same material. Since a small portion of the mesh will always be close to the renderpoint in the VW, culling can not occur. The use of culling could drastically improve performance.

The workflow specified in this thesis uses dynamic lighting in contrary to static lighting. The use of static lighting was not possible with the use of the DAE format. The reason lies in the way static lighting works. Whenever you create an object in 3D it has a property called “UV-Channels”. These UV channels contain the information in which the texture is saved and how lighting affects it. Whenever in a static lighting environment lighting is created, it is build for the current scene. This way the 3D software saves the “way” of how the light affects a certain object. Unwrapping of these UV-channels is a heavy task and a resourceful one. Texturing a 3D model correctly would mean to first assign textures, then render lighting. After this process is done the result, a texture with lighting on it, is saved to a renderfile. Texture renders such as these have a specific resolution. Unwrapping big meshes produced by the DAE format would result in very low detail UV unwraps, since all polygons need to be fitted within a 2048p x 2048p texture render (an already somewhat bigger size).

Nevertheless the choice for DAE was made due to the fact that the process had to be mainly automated and as less manual work as possible. We do believe that the results acquired within this project are one of the best considering the alternatives.
6.2 Future work

In the introduction of this thesis notions were made in regard to certain types of simulations. The result produced by this thesis is a cornerstone for some of these simulations thus further research can be done in this field.

For some of the simulations described in the introduction the model produced may not be as valuable. This is due to the type of computer model the result became. Simulations such as escape routes, people mass analysis may proof to be more effective on a less dimensional and graphical representation of the model. Nevertheless fire simulations for example or optimal use of space for interior design, do benefit from the graphical and higher dimensional representation of this model.
7.1 Summary

The creation of a VW from an architectural data source is not a trivial task. After construction of a general workflow for this task it is applied to the case study. The result, an optimized 3D model, can be imported in a game engine that supports VW. After the creation of the virtual environment with the optimized model the VW is evaluated. The result is a smooth experience which closely matches the artistic impression provided by the architectural bureau.

7.2 Research question

Are data sources produced by architects suitable for “virtual walkthrough” simulations, and if so; what is necessary to produce such a simulation?

Raw data sources supplied by architects are not suitable sources for VWs. In order to make them suitable a number of conversion and optimization steps are required. The level of optimization that is required depends on the size of the input model. For smaller models, some optimization steps may be omitted if performance is sufficient. The workflow described in this thesis includes an iterative component that optimizes until acceptable performance is attained. The resulting model is then used in the gaming engine for the creation of the VW.

7.3 Application

The VW produced from the NU Project can be used for informing employees of the University of Amsterdam and the Vrije Universiteit. Displaying the VW can not only be done with the use of an HMD but also with the normal use of a monitor. Any suggestions or questions regarding the building can then be discussed with the contractor, providing feedback in an early stage of the building process.

Furthermore, the workflow designed in this thesis can be for other projects that use the Revit format. We believe we have lowered the bar for the integration of VWs in architectural design.
Appendices
APPENDIX A

Graphical comparison of the result and artistic impression
Figure A.1: Comparison of Artistic view with resulting VW.
Figure A.2: Comparison of Artistic view with resulting VW.
Figure A.3: Comparison of Artistic view with resulting VW.
Figure A.4: Comparison of Artistic view with resulting VW.
Figure A.5: Comparison of Artistic view with resulting VW.


[27] Marc Treer. Requirements to work in the top 50 architecture firms.”, journal =.


