Virtual Reality for Modular Construction in Industrial Heritage.

Creative Technology graduation project

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Abstract

To combat the increasing housing shortage in the Netherlands, a concept to build modular homes inside industrial heritage buildings is being developed. This report investigates how a VR application could be developed and used to familiarize potential renters with a modular-home; and how it could aid in convincing city council members of the added benefit of modular building in industrial heritage buildings.

After co-developing with the client, and evaluating a prototype three times, two final prototypes were realized that could serve these purposes. The first prototype focusses on immersing the potential renters in a virtual environment resembling the conceptualized modular homes; while offering various customization options to familiarize the user with the home while giving them a feeling of ownership. The second prototype is aimed at city council members and offers a simple interactive tour that informs the user about the 'modular construction in industrial heritage' concept; with the intent to convince them about the added benefits of said concept.

Finally, future improvements of the prototypes are discussed, to guide the client in further development of these or similar applications.

Contents

Chapter 1: Introduction

1.1 Background

The Netherlands has a large deficiency in housing, according to the Dutch state-government there is an approximated shortage of 331.000 living spaces, which will increase to an estimated 845.000 by 2030 [1]. This makes it increasingly harder for starters, and people with an average or lower income to find a place to live. Many companies in the housing-construction business try to meet the demand, and build as many living spaces as possible, but their progress is limited by the fact that they are running low on employees and building materials [2].

One solution to this problem that has been attempted over the past few years in many countries is the reuse of vacant buildings for housing. With minor or major interventions, depending on the state and shape of the structure, buildings can be redesigned to serve as housing. This method has proven to be sustainable and effective at increasing the amount of available living spaces [3].

Innovationhub Salland is planning to build modular, box-shaped apartments in industrial heritage buildings. They call this project “doos-in-doos” or box-in-box (see figure 1.1). By fitting the individual parts through the existing entries of the buildings, or through as-small-as-possible new entry-ways, these apartments can be constructed relatively easily. This solution will also cost less labor than traditional construction methods and will save materials by making use of the existing vacant buildings. Contrary to the aforementioned projects however, close to no renovations will need to be made on the reused buildings, because of the modular nature of the box-shaped living spaces. This modular nature could also prove to be a more sustainable solution because of its reusability.

Figure 1.1: 3D render of the first iteration of the “doos-in-doos” project.

1.2 Problem statement & goal

The idea of modular building is quite new, and modular building inside of industrial heritage has never been done before. This means that city councils that decide what happens to these buildings still need to be convinced that this project will not harm the existing architecture; will add to the appeal of the building; and is desirable in general. The same goes for potential renters, the concept might seem weird to them, and since the first version of this concept has not been built yet, they cannot get a viewing in real-life.

The Innovationhub thought that showing the concept of the project in a three-dimensional (3D) Virtual reality (VR) environment will generate enough context for the city council members to help convince them of the added benefits of the concept. This idea was partially backed by a study from 2020 by Pleyers and Poncin [4], where it was found that, in general, people who are exposed to a property through VR instead of a 2D image, have a higher chance to visit the property in real-life and have a more positive attitude towards the property and realtor.

This is why the goal of this project was to develop a VR application that could be used to familiarize potential renters with a modular-home; and to aid in convincing city council members of the added benefit of modular building in industrial heritage.

To investigate the needs of the parties mentioned in the goal statement, while also aiding in the development of the application required to reach this goal, two research questions are formulated:

> *RQ1: How can an intuitive VR application be used to familiarize potential renters with a modular-home?*
>
> *RQ2: How can VR be used to convince city council members of the added benefit of modular building in industrial heritage?*

To aid in meeting the specified goal, four guiding sub questions have been formulated:

> *SQ1 In what unique way does VR influence someone's attitude towards a property?*
> *SQ2 How does UI design aid in making a VR application intuitive?*
> *SQ3 What benefit can VR bring to the property selling process that other mediums cannot?*
> *SQ4 How do you make a VR application intuitive to use, without external guidance?*

SQ1 to SQ3 will be researched in Chapter 2: State of the art. SQ4 will be answered by analyzing and applying the findings gathered from the evaluation phases described in Chapter 5.

Chapter 2: State of the art on virtual reality in real estate

2.1 Expert interview

The client's problem statement (Appendix 1) was rather broad and did not define one single problem that could be solved, instead multiple problems were proposed that all had VR as their starting point. To define where the problem exactly laid, an expert interview was conducted with the client, who was the primary contact person during this project. The client is the head designer at Mensink construction company, which is one of the four companies that forms the Innovation Hub.

> According to the client, the main focus for the box-in-box project is to create starter housing at an affordable price while preserving monumental buildings. Next to this, they want to break through the currently prevalent traditional practices used in construction, to promote innovative problem solving in the sector.
> Due to this novelty however, he expects there will be troubles when proposing the idea to city councils. The concept is still rather abstract and there is not much context or previous work to show as a prove of concept. That is where VR comes in, the company already uses VR to bring customers to conceptualized homes, but never in an interactive manner. The users are only shown 3D static images, which do not allow for any form of exploration. A more interactive application could serve to inform city councils, as well as potential renters, of the novel concept.

With these answers in mind, the state of the art research began. It was clear that the focus of the project would be on developing a user centered VR application. To find out where innovation could take place in the realm of VR for real estate, an exploration and analysis on a selection of the currently used VR applications and other related works in this field were conducted (see Chapter 2.3).

2.2 Benefits of applying VR in real estate

A big reason why VR has been growing more popular in real estate is the fact that it offers alternatives for conventional property viewings. This gives people who are looking for a new home the opportunity to look at properties that would normally be too far away, or even at properties that do not exist yet.

2.2.1 Virtual property tours for customers

Nowadays many people choose to buy a property 'off-the-plan', meaning that it has not been built yet. Because of the ongoing rise of property prices, buying the house early in this way may result in a better deal for the customer [5]. However, because the property has not been built yet, the customer has to base their decision to invest in the property on 2D drawings or 3D renders at best. This makes it difficult to grasp what the final house will look like and if it will fit their expectations. To solve this problem, various VR applications can be deployed. These applications allow the customer to walk through the house as if they are there in person, even before it has been built.

By using techniques of 3D scanning and uploading living spaces, the realtors can organize long-distance property viewings through VR. This gives prospective buyers an immersive walkthrough of the house before a showing, or an alternative to a physical visit. Taking customers on virtual tours additionally allows them to make a selection of properties that are more in-line with their wishes. This saves both parties time and money. Next to this, using 3D scans can offer the unique feature of presenting a version a the property that is still furnished, even if the original owner has already moved out.

Coldwell Banker Real Estate [6] found that 62% of sellers would choose a realtor that gave them the option to present their home through this medium over one that would not. Additionally, having a digital depiction of a furnished version of the property available, even after the client has moved out, offers a great advantage in marketing [6]. In their research they also found that 77% of Americans, if they were presented with the option, would want to see a house in VR first, before visiting it.

2.2.2 Sense of presence in VR for real estate

In a study conducted by Pleyers and Poncin. [4], an interesting benefit of applying VR during the house searching process was found. In the study, participants were exposed to a fictitious real estate website that either presented them with pictures of a house, or with a 'non-immersive VR' depiction of the house. non-immersive VR is a form of VR where the user can move through some form of virtual environment, but without the use of a head mounted display, using a conventional display instead. This non-immersive VR depiction allowed participants to get a 360º view of the property in a 'Google street view' type fashion.

Unsurprisingly, it was found that participants who were exposed to the VR version of the website experienced a greater feeling of presence than those who were not. Presence is a psychological state in which the user feels immersed to such a degree in the virtual environment that they feel as if they are physically present. It was also found that this sense of presence increased the participant's willingness to visit the property in real life.

Wallach and Safir [7] and Morélot et al. [10] researched how the feeling of presence can be heightened. It was found that there is a link between immersion and the sense of presence that a user experiences. Through hardware this immersion can be enhanced by creating stereoscopic visuals or increasing the field of view. It was also found that head-mounted displays do a better job at this than flat screens, as long as the device is not cumbersome or uncomfortable to use [7]. These displays allow the user to explore beyond the edges of the screen and add representation of the user's actions in the virtual environment (VE). Giving the user control over the VE and letting them have meaningful interactions with objects in the VE also improves the feeling of immersion. This happens both directly and indirectly. Directly by increasing the involvement or engagement of the user, and indirectly by suspending the user's disbelief in the VE [7].

2.3 Related existing software

Applying VR in real estate is a relatively new concept, but it has already led to the development of various applications made to help realtors and prospective buyers in the process of selling or buying a house, respectively. By conducting a brief exploration on some examples of currently available software, insight in the field, as well as possible gaps in functionalities or features, can be established.

2.3.1 Examples of related software

Matterport

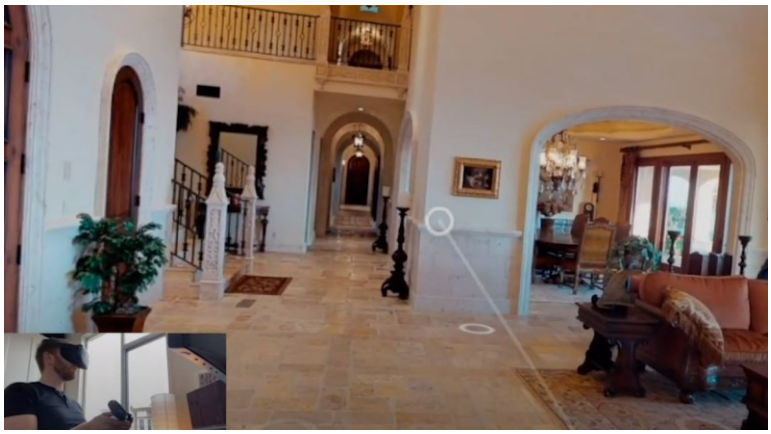


Figure 2.1: showcase of VR mode for Matterport 3d viewer.

Matterport is a 3D scanning software that allows users to create detailed 3D models of their house, including furniture and decorations [14]. These models can then be published to be viewed in a "Google street view" manner (panoramic view) or in VR (see figure 2.1).

Atlas Bay VR

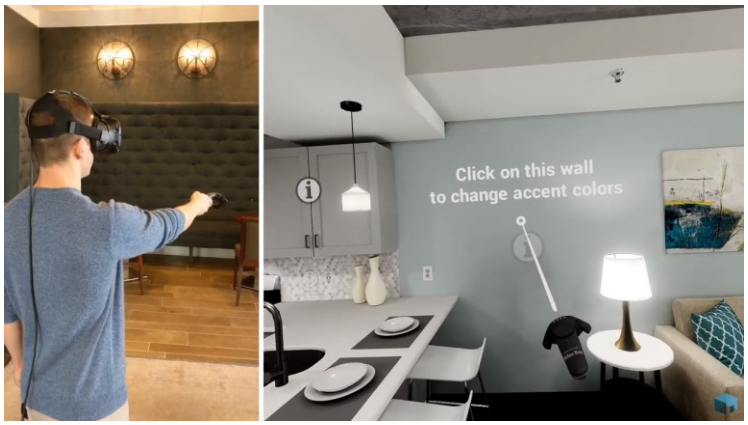


Figure 2.2: showcase of High-End Virtual Reality for Real Estate tool by Atlas Bay.

Atlas Bay developed the app "*High-End Virtual Reality for Real Estate*" that allows customers to walk through 3D scans or renders of properties and lets them interact with the design [15]. The user has the option to manipulate various objects, for example turning lights on and off; opening and closing closets; and changing the colors of walls (see figure 2.2). This interaction helps with giving the user a greater sense of presence. [4]

Room designer VR

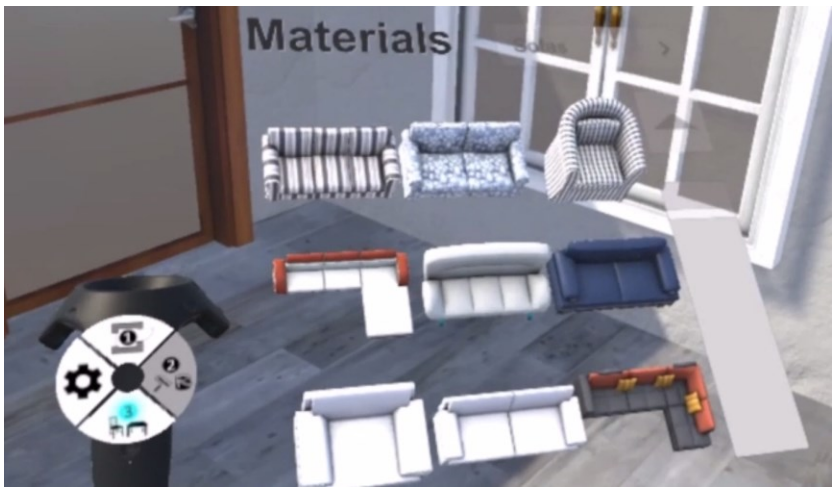


Figure 2.3: Showcase of Room designer VR functionality.

Room designer VR is an application that allows the user to create a room based on a 2D floorplan. This room can then be customized and furnished through interactive menus in VR. The option to import custom 3D models for furniture or complete houses is not present however [16].

Creatomus

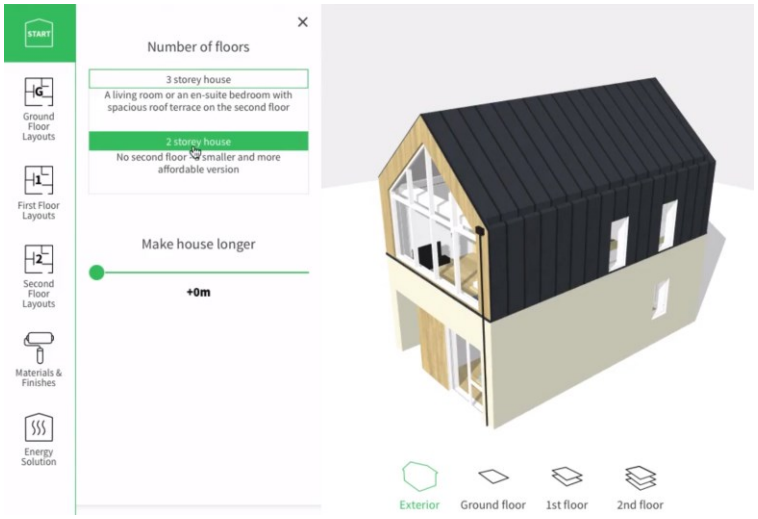


Figure 2.4: interface showcase of Creatomus custom housing tool.
Accessed on 13 April 2021 *from https://www.creatomus.com/*

As this project is not solely focused on VR in real estate, but also on customizability and modularity, The Creatomus house configurator is an interesting tool to learn from. It is a tool that allows customers to design their own build-to-order home by choosing from a list of options that the manufacturer offers. Additionally, the tool gives a price estimate based on the chosen parts and dimensions. The tool can also be utilized by retailers to give customers a quick overview of the options that they offer.

2.3.2 Conclusions from presented examples

	Free movement	**Customized furnishing**	**accessible for new VR users**	**VR compatible**
Matterport	absent	absent	present	present
Atlas Bay VR	present	absent	present	present
Room-designer VR	present	present	absent	present
Creatomus	DNA	present	DNA	absent

table 2.1

The discussed applications all contain features that are interesting for the development of the tool specified in section 1.2. However, It was also found that there is currently no software available that covers all of these features (see table 2.1).

Taking the type of personalization interactions that are present in Atlas Bay's '*High-End Virtual Reality for Real Estate*'; combining these with the furniture interactions seen in "Room designer VR"; while still allowing for free movement in the virtual living space; will be a good starting point in the development of a tool that can reach the goals mentioned in Section 1.2

2.4 virtual reality user interfaces

The user interface is one of the most important aspects of any software that tries to sell a product or to convince the user of something. Creating a seamless experience for the user also aids in creating a heightened feeling of presence. This section gives an outline of the established design principles that are used to create these interfaces and interactions. As well a summary of conclusions from related studies.

2.4.1 Object manipulation

Sun et al. [8] found that in VR object manipulation, free dragging control should be chosen over proxy control (meaning movement through the use of x, y and z handles). from the results of the research conducted in [8] it was also concluded that participants experienced the highest level of comfort at a 1:10 scale when working with an architecture related task in VR.

2.4.2 UI placement

The results from Fu and Li [9] showed that a Virtual World Reference Frame (VWRF) interface positioning increases the feeling of presence and additionally helps the user with a sense of direction in relation to the real world. Simply put, a UI system that uses a VWRF is statically linked to a certain spot in the VE. This means that, when the user moves their head or body, the interface will not follow this movement, but will instead be "stuck" to the virtual space.

When the UI is linked to the screen space, meaning that it will follow the head movement and looks as if it were stuck to the lenses of the HMD, the interaction can feel nauseating in VR.

To illustrate the reference frames, Iron Man [17] can be taken as an example. In his suit he has a screen space reference frame, the UI is in front of his face and moves along with him (fig. 2.4). In his office however, he has a static hologram UI that he can look at from different sides (fig. 2.5).

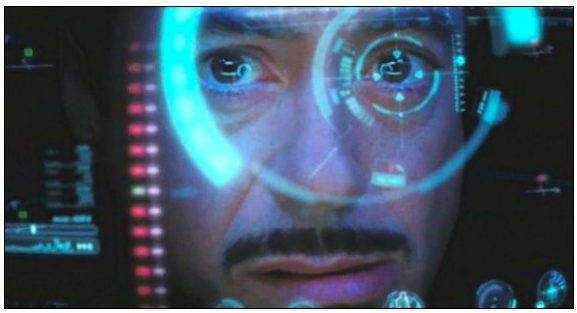


figure 2.4

figure 2.5

2.4.3 Intuitive menu design

When designing menus, the buttons should look like they are pressable, communicating their function. Following modern design trends, neumorphism should be used as a starting point, this has the same function as skeuomorphism, but with a cleaner and more legible look to it [11] (see figure 2.6). Skeuomorphism is a design style where a software object mimics its real world counterpart. In this example that means making to digital buttons look like real buttons in order to inform the user that these buttons are clickable. Neomorphism is a new version of skeuomorphism, where the same principles for intuitiveness were kept, but with a modernized look. A flat design should be avoided, as it does not offer the same level of intuitiveness as the other two design methods.

Figure 2.6

neumorphism *skeuomorphism* *flat design*

To communicate the state, or a state change of the button, visual (see figure 2.8) and audible cues should be used. When the hardware allows it, haptic feedback can also be implemented.

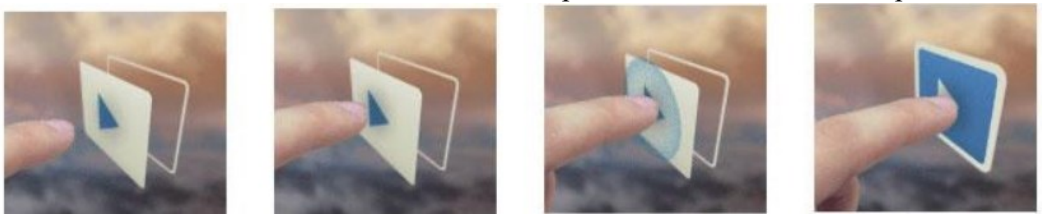


figure 2.8

2.4.4 Content zones

Alger [11] specifies that there are three main zones that need to be considered when designing an Interaction interface:

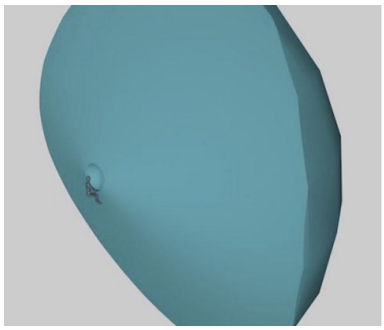


Figure 2.9: content zone

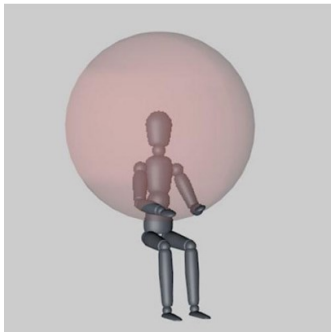


Figure 2.10" "no-no" zone

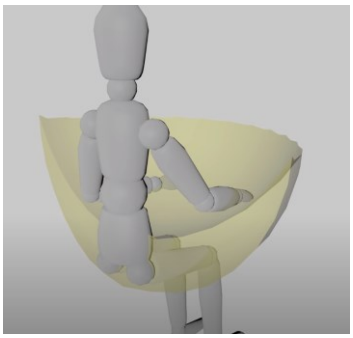


Figure 2.11:touch-interface zone

When sitting down, the content zone is the zone that can be comfortably viewed in VR (see figure 2.9). This zone stretches up to approximately 20 meters before the image becomes too obscure.

The "no-no" zone is the part of the visable content that is too close to the user to be viewed without becoming cross-eyed, this area is within 0.5-1 meters of the user's eyes (see figure 2.10). When designing an interaction, placing parts of the UI in this area should be avoided.

The touch-interface zone is the part of the content zone that is within arm's reach, preferably within 2/3 of an arm length to avoid fatigue (see figure 2.11).

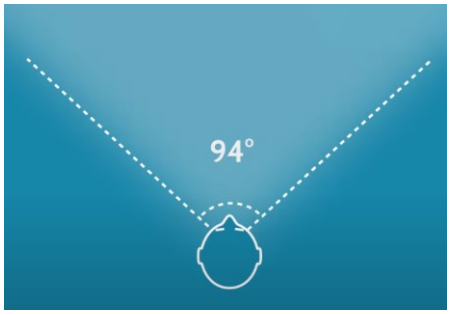


Figure 2.12: Field of view (FOV)

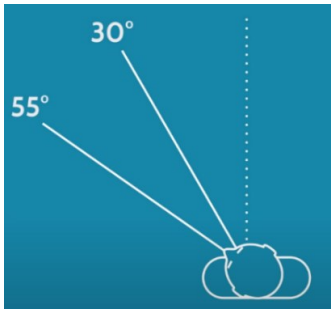


Figure 2.13: Comfortable & max head-rotation

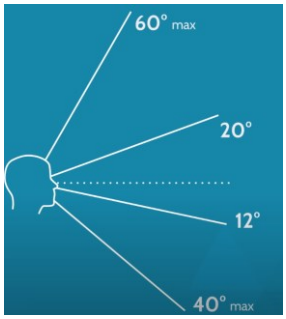


Figure 2.14: comfortable & max up and down rotation

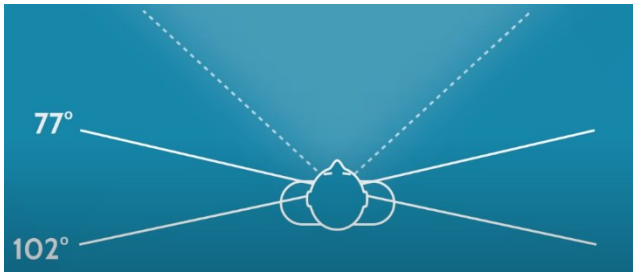


Figure 2.15: Viewing & straining angles

To find the dimensions of the content zone, human biomechanics should be considered. Without straining, the user can look left and right 77° (see figure 2.15), up 20° and down 40° (see figure 2.14). this visible area forms the "main content zone". The areas that can be viewed by the user while straining is the peripheral zone, it can be used effectively, but only for short periods of

time. These peripheral zone consists of the outer limits seen in figures 2.13 to 2.15. The field of view (FOV) seen in Figure 2.12 and the inner limits seen in Figure 2.14 form the area that is visible to the user without them moving their head.

2.4.5 Considerations for UX design

As a designer it can be easy to lose track of the user's needs, this can lead to faulty assumptions during the design process which leads to a final product that does not fit the user's needs. For VR development, it should be assumed that the user has never used VR before and needs to be introduced to the medium. This can happen through progressive familiarization, by slowly exposing the user to new functions, while being guided by the software [12].

Another consideration that needs to be taken into account is the risk of simulator sickness. In VR locomotion, there is a mismatch between the user's perceived movement and the actual movement. Kaufeld and Alexander [13] found that the chance that a user experiences simulator sickness is largely dependent on personal factors, so it cannot fully be taken into account in the design process. Adapting movement alternatives such as teleportation or snap rotation (rotating by a fixed angle instead of continuous movement) can however help alleviate or avoid the symptoms of simulator sickness.

2.5 Conclusions

As shown in section 2.2, there are many benefits to the use of VR in the context of the problem statement. By giving users context for the box-in-box project, they can understand the novel concept better, while also getting a detailed look at the yet to be built houses. Additional found functions of VR in real estate are: long-distance property viewings; furnished viewings of empty houses; customizable furniture and room designs; and a heightened sense of presence.

The sense of presence was found to be an important factor in the process of selling properties, and increased the participant's willingness to visit the property in real life. To increase the sense of presence, the user should be able to: move freely through the environment; have meaningful interactions with objects in the environment; and should be able to influence the state or shape of the environment.

When designing the user interface, some basic design principles as well as considerations of human ergonomics should be kept in mind. To make the interface intuitive, neumorphic design principles should be applied, combined with visual, audible and haptic feedback where possible.

To make the interface comfortable to use, it should be restricted to the recommended content zones discussed in 2.4.4. If the goal of the application is not productivity, a virtual world reference frame should be used for the interface, to ensure comfort once more and to avoid simulator sickness. Other methods that can be implemented to avoid simulator sickness, when needed, are teleportation and snap rotation.

Chapter 3: Ideation

In Chapter 2: State of the art, it was identified where a gap still exist in currently available VR software for real estate. This chapter will explain how the findings from Chapter 2 were used to co-design an application with the client to answer the research questions specified in Chapter 1.

Stakeholders

Now that the direction of the project was defined, the exact users and their needs had to be determined. A meeting was organized together with the client, the secondary contact person and another Creative Technology student researching the same problem statement. In this meeting the first step was to define the stakeholders for the given problem statement:

1. **Project planners** – Their job is to find buildings that are suitable for the box-in-box project; informing and convincing city councils about the box-in-box project; advertising the innovative living spaces to the potential renters; organizing the construction activities and sufficiently communicating relevant information to construction workers and contractors.

2. **Construction workers and contractors** – this group will be responsible for the creation of modular home layouts in the overarching structures, as well as the assembly of said homes. It is important that strong communication exists between this group of stakeholders and the project planners, as the box-in-box project is novel and might call for never before used construction techniques.

3. **City councils** – This group's main concern is to find out if the box-in-box project is a suitable initiative for their town and if the buildings selected by the project planners are not better used for a different purpose. This is one of the groups that will be advertised to by this project, meaning that they will have to be considered extra carefully in the following design steps of the VR project, both in a usability context and an ethical context.

4. **Potential renters** – This group was defined as young starters who are looking to invest in their first 'real' homes. This group's own interest is to judge if the box-in-box project fits their needs, they are also being advertised to however, and it is in the project planner's interest to rent the homes out as fast as possible. This means that it is just as important for this group to be handled at high ethical standards, to avoid deception and maintain the user's autonomy.

With the direction of the project as well as its users defined, the exact user group and goal for the VR project had to be established. This was required since it would be impossible to solve all problems for all stakeholders with one single application. The second step in the meeting was to define which functions would be meaningful for any of the groups of stakeholders. After passing an amount of ideas back and forth, it was concluded that two applications could be developed with two sub-versions for more specific user groups.

Application 1: A VR tool that lets potential renters walk around in the overarching building and the modular homes. Inside the homes they should have the ability to customize the home to give them a feeling of ownership, and to show them the options Mensink would be able to offer.

Sub-Application 1: An automated, narrated tour through the same building and homes as used for Application 1, but catered towards less tech-savvy people. It was decided that this functionality would be of value, since city council members are generally older than the potential renters and research by Hong et al. [18] has shown that age has a significant influence on game performance in VR. Adding this functionality would solve a second problem without the need for a completely new application.

Application 2: A VR tool that lets construction workers plan and practice the entry of modular parts into the overarching buildings.

Sub-Application 2: An adaptation of Application 2 that lets city council members view or place the individual homes into the overarching buildings. This generates context for them and familiarized them with the concept while also catering more fluent back and forward communication.

(Sub-)Application 1 was ultimately selected for this research report, and (Sub-)Application 2 was selected by the other Creative Technology student for his report..

Chapter 4: Requirements and Specification

With the user groups defined and an idea for the application established, the functionalities of said application had to be determined. This chapter serves to explain the different steps and tools that were used to determine the requirements for the stakeholders.

4.1 User factors

User factors were first established, to keep the design user-centered and to not lose track of the purpose that the application would have to fulfill. Next to this, the user factors served to identify specific topics fit for usability testing, this will be further discussed in Chapter 5.

The client was consulted for a half open interview to discuss which user factors and scenarios would be important to take into account. The prepared discussion points for the interview can be found in Appendix 2.

Based on information gathered from the interview, as well as the state of the art research, user factors for the different groups of relevant stakeholders were established, following the method from [19]:

1. Potential renters

Background: who are the users? – The users are young starters who are looking for their first house. The client's project is not focused at older people or students. This user group is already familiar with basic technologies such as smartphones, are very likely to have experience with video games and might have experience with a form of VR. There is however a big group within this demographic that has no previous experience with gaming with a controller nor with VR.

Motivations: **what goals do they want to achieve?** – The users want to find out if the product that the client offers fits their needs. The concept is novel and can sound confusing when you do not see the concept in its physical context, this means that the user wants to find this context I order to properly form an opinion about the concept.

Tasks: **what must they do to reach those goals?** – To find this context, the user needs to engage with the project by contacting the realtor (Mensink), the realtor will offer the user the tools they need to gain insights into the workings of the project and what the user can expect from it.

Context of use: **how will they encounter your design?**

1. **Environment** – **where will they try to use it?** – If convenient enough, the user will visit the office of the client and use the application at that location. When the user lives further away, the client can send a VR headset to them instead.

2. **Challenges** – **when they try to use it, what can get in their way?** – Using VR or even joystick controls for the first time can be very confusing and not self-explanatory. For VR the user also needs a space that is big enough to walk around in and safely interact with the VE without hurting themselves or their belongings. Motion sickness can also pose a problem in longer sessions

2. City council members

Background: who are the users? The users are, often middle-aged, city council members looking to assess the box-in-box project. This user group has basic knowledge of common technologies such as smartphones, but will most likely have little to no experience with video games or VR.

Motivations: **what goals do they want to achieve?** – Their main interest is to find out if the box-in-box project is a suitable initiative for their respective city, and if the selected buildings are not better used for a different purpose. The concept is novel and sounds confusing without proper explanations and visualizations of the concept, so the user wants to find clarity about the concept, in order to assess it more accurately.

Tasks: **what must they do to reach those goals?** – To gain the required clarity, the user will be contacted by the realtor(Mensink), the realtor will offer the user the tools they need to gain insights into the workings of the project and what the user can expect from it.

Context of use: **how will they encounter your design?**

1. **Environment** – **where will they try to use it?** – Depending on the situation, the user will either visit the office of the client and use the application at that location, or be visited by the client and use the application at their own office.

2. **Challenges** – **when they try to use it, what can get in their way?** – Using VR or even joystick controls for the first time can be very confusing and not self-explanatory. For VR the user also needs a space that is big enough to walk around in and safely interact with the VE without hurting themselves or their belongings. There is also the possibility that learning how to use VR within a short time span is too difficult for this user group, meaning that a specifically interactive VR experience might not be an option for some people from this user group.

4.2 Prioritization

The various user factors specified in the previous section all called for different functionalities and features that could be added to the final application. Due to the given time constraint for this project however, a prioritization order had to be established for said functionalities and features. A common tool used in these types of situations is the MoSCoW method. It is a prioritization technique used to manage requirements and consists of four categories: 'Must haves', 'Should haves', 'Could haves' and 'Won't haves'. The four categories are ordered by how essential they are, and proposed functionalities should be assigned to these four categories as such.

From the interview, meeting, and user factors analysis, twelve functionalities were established and ordered as follows:

Must have:

- VR depiction of how the box-in-box project will look from a first person perspective
- Free movement through the virtual environment
- Meaningful interaction by influencing the layout of at least one house's furniture

Should have:

- Short introduction to VR tutorial (separate level within the application or printed version)
- Teleportation and snap turning to reduce motion sickness
- Ability to change to different furniture options
- Automatic (narrated) locomotion tour, aimed more at the local councils

Could have:

- Price estimation based on the selected options
- Option to load in own furniture or something that looks similar to what the user already owns
- Backwards compatibility to load in different 3D models of overarching buildings, modular houses and furniture

Will not have:

- Realistic HD textures
- Customization of the modular house's structure (different roof, longer walls, bigger bathroom etc.) but depends on needs of the client and what they can offer the user in real life

4.3 Specification

1. **VR depiction of how the box-in-box project will look from a first person perspective (must-have) –** As established in section 2.2, there are benefits of applying (immersive) VR in real estate. Offering users a first person perspective in the houses through VR will give them, as well as the clients, all of the respective benefits discussed in said section.

2. **Free movement through the virtual-environment (must-have) –** This feature is what would set the developed application apart from the related existing software discussed in section 2.3. Most of the VR application discussed there only offer the user the option to teleport to snapping points where 3D pictures of the space have been made. Offering free movement to the users would allow them to explore the full building and familiarize themselves more with the box-in-box concept.

3. **Meaningful interaction by influencing the layout of at least one house's furniture (must-have) –** As discussed in section 2.2.3, creating meaningful interactions has been proven to be one of the most effective ways to enhance the feeling of immersion and presence in a given VR environment. This feature was additionally selected to be a must-have based on its ability to create a feeling of ownership for the user [4]

4. **Short introduction to VR tutorial (should-have) –** VR can be a confusing medium when using it for the first time, even when intuitive design is taken into account. User testing will determine the actual importance of this feature. However, to avoid new users from getting 'stuck' with the software, a simple explanation of the controls can be added as an insurance policy.

5. **Teleportation and snap turning (should-have) –** As determined in section 2.4.5, movement alternatives such as teleportation and snap-rotation can help alleviate the symptoms of simulator sickness, or avoid them altogether.

6. **Ability to change to different furniture options (should-have) –** This is a further developed version of feature 3. and should be added for the same reasons. Giving users the option to choose the furniture that is present in the room instead of only being able to rearrange the present furniture will make the house feel more personalized.

7. **Automatic (narrated) locomotion tour (should-have) –** Creating a version of the application that is instantly usable without the need to familiarize with a new medium or unfamiliar controls, will broaden the possible user base.

8. **Price estimation based on the selected options (could-have) –** Users could in theory add an infinite number of furniture pieces to the house, if the currently proposed must-have and should-have features were to be implemented. To combat this problem, while additionally giving the users an insight in the price of their selected options, this feature could be implemented.

9. **Option to load in own furniture (could-have) –** To take the possibilities and effectiveness of feature 3. to the highest level, the option to load in items that the user themselves own could be added. It is however expected that the time this would take to implement would not weigh up to the marginal gains experienced when doing so.

10. **Backwards compatibility to load in different overarching buildings or modular house 3D models (could-have) –** This would be a great feature to have when considering the goals of the application. The process to create these 3D buildings is rather complex however, and is better conducted in the dedicated software applications discussed in section 3.2. Importing these models to Unity once they have been created in the dedicated software would however be possible.

11. **Realistic HD textures (won't-have) –** For the believability of the virtual environment, HD textures would work very well. When working with VR however, application performance has to be taken into account. High definition textures, as well as highly detailed 3D models, will lead to lowered frame rates, which can in turn lead to motion sickness and a less enjoyable experience in general.

12. **Customization of the modular house's structure (won't-have) –** This feature was seen in the desktop application 'Creatomus' (section 2.3.1). Having a VR version of this same functionality could be fun for users. It turned out however that this is not the direction that the Innovation Hub intends to take this project in.

Chapter 5: Realization and Evaluation

5.1 Deployed software tools

ArchiCAD

The client's primary field is architecture, which meant that all relevant 3d models and layouts were made in industry standard software for this field: ArchiCAD. ArchiCAD is a software tool used by architects during all phases of the design process to conceptualize, design and plan constructions [20].

During the development of this project, the ArchiCAD software was deployed again to convert the supplied .DWG (ArchiCAD 3D object file format) files to the more versatile .fbx 3D file format. This conversion was needed in order to import the files into Unity. To convert the .DWG file to .fbx, it first had to be exported to SketchUp Pro.

SketchUp Pro

Next to ArchiCAD, the designers from the client's company use SketchUp Pro in the later stages of the design process. The software is mainly used for furnishing and more intricate design steps.

During the development of this project, SketchUp Pro was used for the conversion from the .DWG to the .fbx file type, as well as for its extensive library of 3D furniture models. In SketchUp the imported .DWG file could be exported as .fbx to Autodesk Maya in order to clean up the files and reapply lost textures.

Autodesk Maya

Maya is a 3D computer graphics software application used to create and animate assets for many different types of media. Next to currently being an industry standard, Maya is also the most common 3D software used by Creative Technology students.

For this project Maya was used to process .fbx files, apply materials to assets, create original assets and export said assets to Unity.

Unity

When developing software for VR there are two main choices when looking at development platforms, Unity and Unreal Engine. Though Unreal Engine has many interesting features, Unity was ultimately chosen as a development platform. Unity is more beginner friendly, has more online resources such as forums and video tutorials, and prior experience with this software was already present.

Unity is a multifaceted game engine that allows relatively quick prototyping because of its user friendly drag-and-drop mechanics. Unity makes it easy to apply quick changes to a program and iterate at high a frequency. To aid in this iteration process, the Microsoft mixed reality toolkit (MRTK) and the XR interaction toolkit were applied, these are specially developed toolkits that make development for VR in Unity more about design and less about coding.

5.2 Required hardware

Oculus Rift S VR headset

The Oculus Rift S is a wired virtual reality headset, this means that an external computer is required in order to send data to the head mounted display. The Rifts S offers 6 degrees of freedom (6-DoF). This means that it cannot only track the user's head rotation, as would be seen in a 3-DoF headset, but also movement over the X,Y and Z axis, allowing it to track the user's relative position (see figure 3.2).

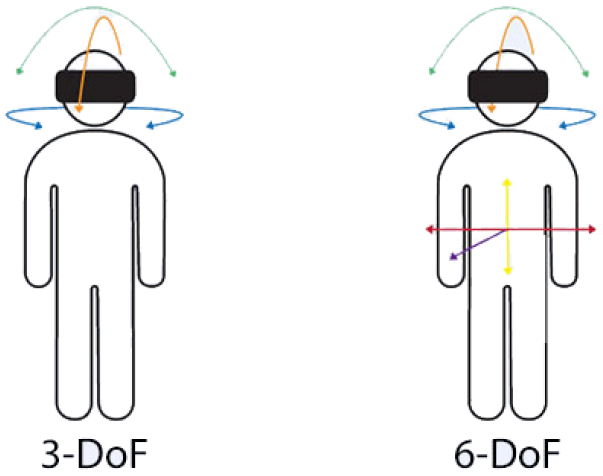


Figure 3.2 3-DoF vs 6-DoF,
Accessed on 26 June 2021 https://virtualspeech.com/blog/degrees-of-freedom-vr

VR compatible computer

When using VR, a high framerate is essential, combining this requirement with the fact that the Rift S has high resolution 2560x1440 screen, asks for a PC with rather high computing power. Oculus provides table 3.1 as their recommended and minimal specifications for a VR capable machine [21]:

Part	**Recommended**	**Minimum**
Video Card	NVIDIA GTX 1060 / AMD Radeon RX 480	Intel i3-6100/AMD Ryzen 3 1200, FX4350
CPU	Intel i5-4590 / AMD Ryzen 5 1500X	NVIDIA GTX 1050 Ti/AMD Radeon RX 470
Memory	8GB RAM or greater	8GB RAM or greater
Video Output	DisplayPort	8GB RAM or greater
USB Ports	1x USB 3.0 port	1x USB 3.0 port
OS	Windows 10	Windows 10

Table 3.1 recommended and minimal specs for Oculus Rift S Accessed on 26 June 2021 https://support.oculus.com/248749509016567/

For the development and evaluation of this particular project a GTX 1060 GPU, Intel i5-6500 CPU, and 16GB of RAM were used, the same specifications or greater are recommended when trying to accurately replicate this project or parts of it.

5.3 Iterations and Evaluations

The following section of this chapter will describe the different steps taken in the realization and evaluation processes of the project. The realization phases focused on iterating and making adjustments to the application based on feedback and findings from the user-tests, which were conducted in the evaluation phases between the developments of each version.

At the start of these phases, co-design had a prominent role and Version 1 of the application was subjected to the client, as well Mensink's 'VR expert', for early evaluation. Based on their feedback a new version was developed which was user-tested twice with the help of two groups of students.

Realization version 1

For this particular prototype, the focus was on creating a realistic experience for the user. An emphasis was put on visual realism in this iteration, to test how far realism could be pushed before the problems stated in feature 11. would arise.

The intended 'must-have' interactions for the prototype were first implemented in a dedicated testing scene in Unity. This made evaluating and adapting easier and promoted working in feedback cycles, even though the feedback would only come from the developers perspective at this point.

The Unity 'XR Interaction' Toolkit was used as a basis for this first prototype, as it has many built-in functions for VR that simplify the design process [22]. The XR Ray Interactor and XR Direct Interactor were applied to accommodate for different types of object manipulation.

The Ray interactor can be used to grab objects from a distance and teleport them to the user's hand (see figure 6.1), this function was implemented in order to allow the user to interact with the objects in the house without having to walk around and reach around too much, as this could become cumbersome. On the other hand, the Direct Interactor was used to add a more realistic experience when interacting with cabinets in the kitchen. This type of interaction requires the user to collide their virtual hand with the object that they intend to interact with before being able to manipulate it, similar to a real-life interaction (see figure 6.2).

To add more clarity to the overall interaction, objects that can be grabbed with the Direct Interactor make the Ray Interactor hidden when it is hovered over these objects. The Ray Interactors additionally switch from red to white whenever they are hovered over an object that they are able to interact with. To add another layer of feedback, the controllers were made to give haptic feedback to the user's hands whenever they were used to hover over an interactable object or to grab it.

In addition to these interaction methods, teleportation, continuous movement and snap-turning were added to the application. This effectively gives the user three options for moving around in the virtual space. Their options are to either physically move and rotate their head in real-life by utilizing the 6 degrees of freedom that the Oculus Rift S headset offers; use the point and click teleportation to instantly move to the desired location (see figure 6.3); or to use the thumb-sticks on the Rift S controllers to move and rotate the player camera as is seen in conventional, non-VR, videogames.

Ray grab interaction

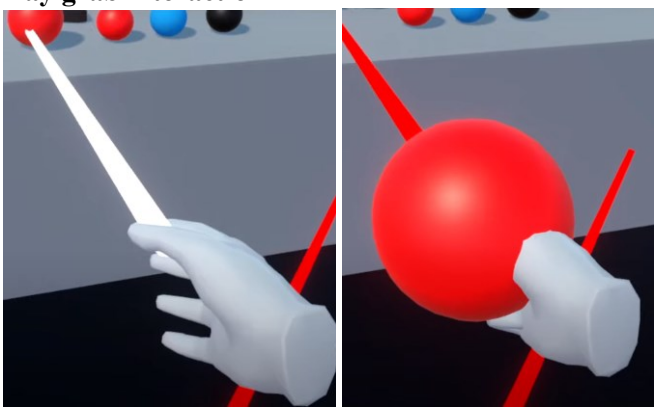


Figure 6.1

Direct grab interaction

Figure 6.2

Teleportation

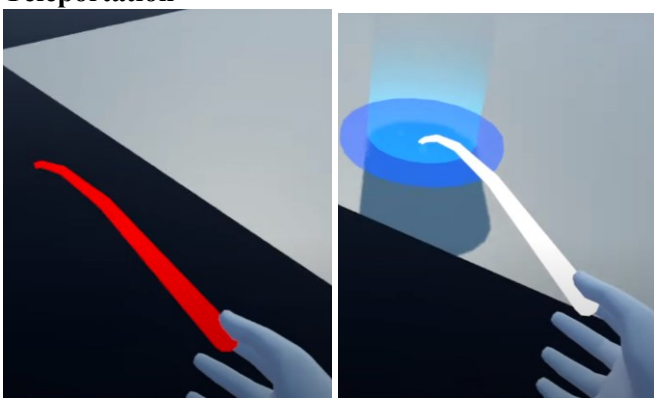


Figure 6.3

Evaluation version 1

Round 1

After completing Version 1, the first evaluation round was conducted in collaboration with the client and his 'VR expert'. They were simply exposed to the first version of the concept to gather if the general direction of the project was appreciated and if there were any functions that should be added or removed.

When the client started using the application, it quickly became apparent that the scene easily becomes chaotic when someone who does not exactly know what is possible in the application tries to use it. The first version of the grab interaction was confusing, and often resulted in the user accidentally grabbing objects from the other side of the room. Next to this, the realistic collision physics caused messy situations, with chairs accidentally being pushed over or thrown away. When the VR expert used the application the same problems arose, although to a lesser extent. During use, the client and VR expert both looked uncomfortable when using the direct interactors, having to bend over to reach cabinets with the direct interactors and losing their balance when using the continuous movement function. When discussing the application afterwards, the client was not impressed by the amount of interaction offered to the user. Additionally he mentioned that it could not be presented to the other stakeholders in its current form, because of the chaotic nature which made it feel unprofessional.

Realization version 2

Based on the comments gathered in round of the evaluations, for the next prototype a quite different approach was taken. The only aspects remaining from the previous prototype at this point were the 3D assets and the insights gained from this intermediate evaluation session with the client.

Instead of the Unity XR Interaction Toolkit, the Microsoft Mixed Reality Toolkit (MRTK) was used. This toolkit does not inherently accommodate the type of realistic object interactions that the XR toolkit could offer, it does however allow for more playful and user friendly interaction design. The goal of this prototype was to create a more meaningful interaction for the user than was seen in the previous prototype and an emphasis was put on increasing the amount of personalization options offered to the user. Room designer VR, as shown in section 2.3.1, was used as an inspiration for the interaction in this prototype.

In this new version, menus offering different types of furniture pieces and other decorations to choose from were placed around the different rooms of the modular home. The menus use a Virtual World Reference Frame as recommended in [21] (see figure 6.4). By scrolling through the lists, users can select coffee tables, plants, televisions, beds, et cetera to place where they desire. The selection type was now limited to a ray-type cursor and direct interaction was omitted, as it was experienced as confusing and somewhat cumbersome in the previous version. The visual realism was also reduced, as a drop in framerate was perceived in version 1 when too many pieces of furniture with detailed textures were placed in the room.

After the feedback session with the client and VR expert regarding Version 1, additionally requested features were added to Version 2. The first request was to add a price indication to options such as different television and cooking top options, to familiarize the user with the options and costs of the modular home (see figure 6.5).

The second request was to remove the ability to throw objects away and have them collide with others, as the realistic feeling added by providing collision between objects worked counteractively, as the collisions quickly felt chaotic and unprofessional when messed around with too much.

The third request was to add an option for people to import their own furniture. This request proved to be difficult to implement, which led to the compromised option to place common popular IKEA furniture pieces. Additionally, the option to rescale the furniture pieces through the use of a bounding box was added, to make the pieces resemble the user's own furniture more (see figure 6.6).

Virtual World Reference Frame menus

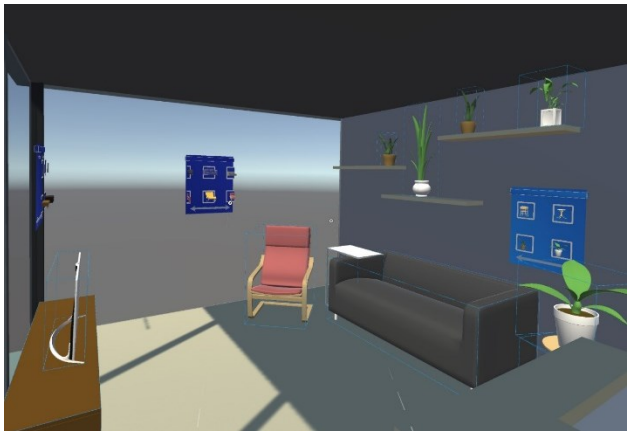


Figure 6.4

Price indicators

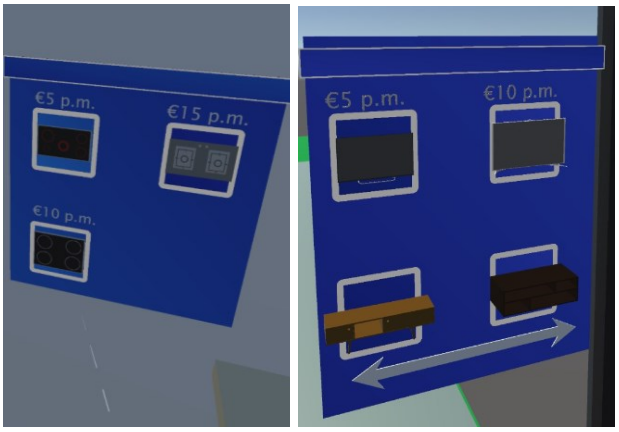


Figure 6.5

Bounding box scaling

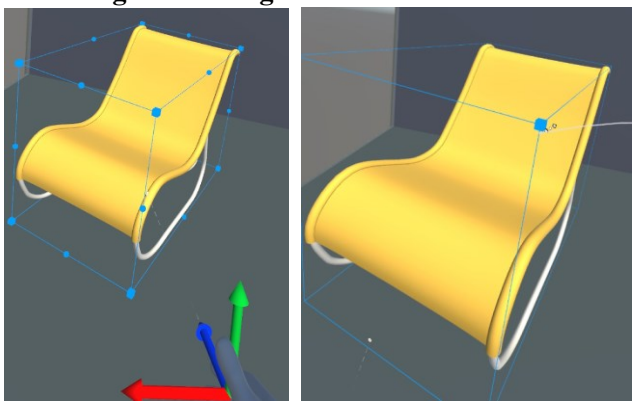


Figure 6.6

Evaluation version 2

For the evaluation of version 2 and 3 of the prototype, the application was subjected to student users in the age-range of potential renters. In both cases a sample size of n=4 was used, this was by no means a group, big enough to gather statistically significant data, but because of the time constraints, as well as the limitations caused by the pandemic, the gathered data was interpreted to be a good indication of the general opinions and experiences with the prototypes.

In both tests the participants were presented with the VR application and 'let loose' to make a room design that they liked. If it became apparent that the participant had not used one or more of the available functions, they were prompted by the researcher to still use the function before ending the interactive part of the test. After the participants had used all functions at least once and had seen all rooms of the modular home, they were asked to remove the VR headset and fill in a questionnaire. The questionnaire contained a mix of open questions and closed questions on a 5 point scale; and ended with a System Usability Scale (SUS) test at the end (see appendix 5). The SUS test can be used to quickly gain an insight in the usability of software and applications. It presents the participant with 10 questions, with a 5 step scale ranging from 'strongly agree' to 'strongly disagree'. The scale then produces a score ranging from 20 (very user unfriendly) to 100 (very user friendly) [23].

Round 2

From this evaluation round it was gathered that the interaction where participants were able to choose furniture from a wider range of options was greatly appreciated. Removing the realistic interactions also did not appear to influence the user's feeling of immersion severely. The participants scored their feeling of presence with an average of 3.75 while rating the realness of the interactions a 2.25. The comfortability also seemed to be improved, being rated a 4.25 on average. The users did however agree that a tutorial at the start would greatly improve their experience, with this question scoring a 4.5. When being asked how clear the controls were the average score was 3.5, this result was however skewed because one of the users was already familiar with VR.

In the open questions various suggestions for improvements were recorded for implementation in version 3 of the application. These will be discussed in the Realization version 3 section.

The average score from the SUS test was 80, with most points being lost on aspects regarding clarity of the available functions, and controls. There was also room for improvement with regards to user retention and a feeling of coherence. All scores and answers can be found in Appendix 6.

From observations it was gathered that the bounding boxes around objects were not intuitive or user friendly, as they were not used a single time by any of the participants. It was also observed that the participants tended to accidentally place too many pieces of furniture, or change their mind on a piece after spawning it and looking for a place to discard it.

Realization version 3

After evaluating Version 2 it was determined that in general the users found the application enjoyable to use, leading to further improvement of this concept instead of developing a third one. The last cycle of the development cycle was used to fix small annoyances, resolve quality of life issues, add more customization and clarify the available features to the user.

First of all, a bin was added to the rooms, this allows users to remove furniture from the room when they do not like it (see figure 6.7); previously this could only be done by dragging it through the floor, which placed it out of their sight.

Secondly, the bounding boxes were removed, as the majority of users ignored them. Instead the furniture could be resized by holding the virtual object with two hands and moving the hands closer and further apart, or rotated by moving the hands as if they were on a steering wheel (see figure 6.8).

Thirdly the option the customize the color of the walls with RGB slider was added, as this customization option was requested by one of the participants in the Evaluation round 2 (see figure 6.9).

Fourthly, the UI was adjusted slightly. In Version 1 it was not clear to the users that they were able to swipe in the different menus. As a reaction to this misunderstanding, an arrow pointing to the left and right was added to imply this option, this however led to users trying to press the arrows to scroll through the list, which was not the intended interaction (see figure 6.10). For Version 3 the UI was thus slightly widened, revealing part of the next item in the list, the intention behind this is to evoke curiosity in the user and see if they try to swipe to the left to reveal the next items in the list. In addition to this, visual and audible feedback was added to the UI to be perceived when the ray interactor is hovered over an item in the list.

Lastly an information pamphlet was designed (see figure 6.11). This pamphlet aids with informing the user on how to wear the VR headset, how to hold the controllers and how to use the application (full resolution can be seen in Appendix 7).

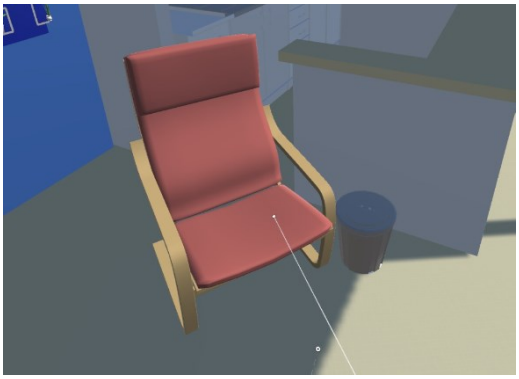


Figure 6.7: Bin interaction

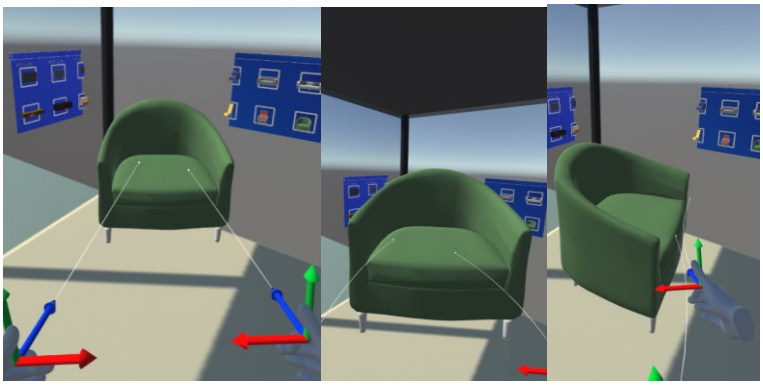


Figure 6.8: Renewed item manipulation

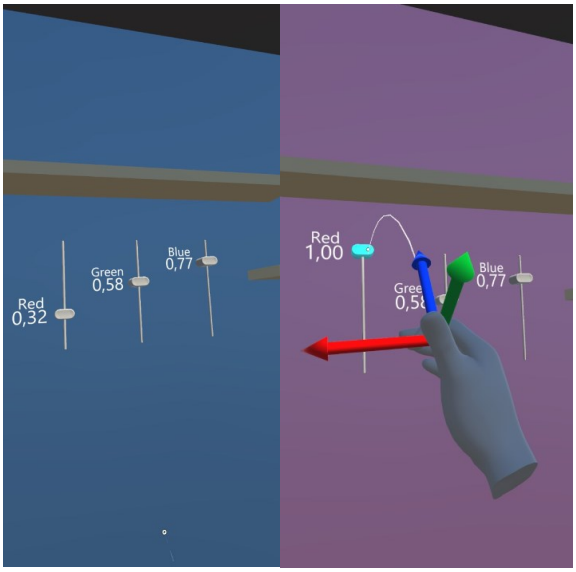
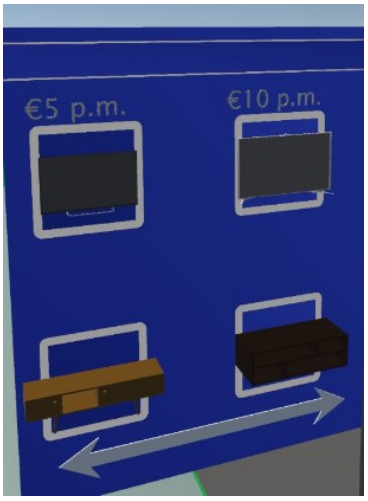


Figure 6.9: RGB sliders

Version 2



Version 3

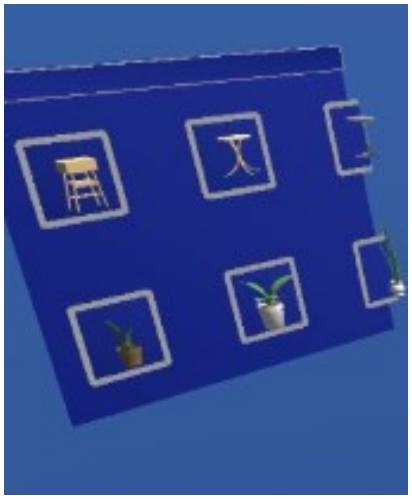


Figure 6.10: UI changes

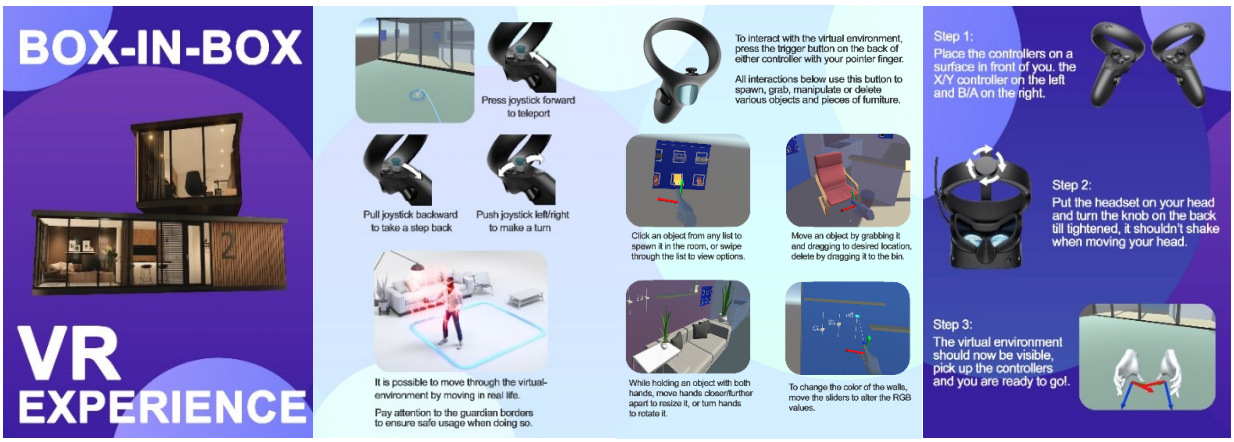


Figure 6.11: Tutorial pamphlet

Evaluation version 3

For the final round of evaluations the protocol described at the start of the Evaluation version 2 section was used again, this time however, the participants were presented with the tutorial pamphlet (see figure 6.11) before being subjected to the application.

Round 3

The feedback gathered in this round was mostly positive and showed that iterating on version 2 based on the feedback from round 2 had improved the experience. Participants now rated the clarity of the controls a 4.75 and gave an average score of 93 on the SUS test.

The open questions did not mention any recommendations for improvements of the functions, they did however mention the need for higher detail; more realistic textures; a greater choice of furniture and the removal of a glitch in the teleportation function.

From observations it was gathered that the item manipulations without the bounding boxes required 2 to 3 minutes of learning before becoming comfortable, but were more intuitive than the previously implemented bounding boxes.

Additionally, intuitiveness of the UI seemed to have increased. In version 2 participants struggled with swiping through the lists of objects even when prompted to; while in version 3 the participants used the swiping in the UI correctly on their first try in 3 out of 4 cases without being prompted to.

Realization Sub-Application 1

As mentioned in Chapter 3, next to the interactive VR experience for potential renters, an easy to use application had to be developed specifically for city council members. The initial idea for this sub application was an automated locomotion tour through the overarching building for the box-in-box project. This idea was however dropped, based on several conclusions gathered in the evaluation section.

Due to the positive feedback on the ability to interact, combined with the perceived motion sickness from automated movement and the effectiveness of the tutorial pamphlet, a different idea was realized. In the new application, the user only has to use one controller and solely the thumbstick on this controller. The same movement types as seen in the final version of Application 1 were used, but the interactions with the trigger at the pointer finger were omitted. Based on the findings from the evaluation, it was hypothesized that this interaction type would be perceived as more positive and immersive than an automated tour.

To make up for the lost automated narration that would be present in the first version of this concept, various human characters were spread through the overarching building instead (see figure 6.12). When pointing the cursor of the controllers at one of these characters, a specific audio file starts playing, explaining something about the room that the user is standing in.

Figure 6.12

Next to this Sub-application, two tutorials were developed. The first one is an adaptation of the pamphlet for the final version of Application 1 (Appendix 7.1), with the third page explaining the interaction with the character models, instead of the interaction with the furniture pieces. The second tutorial is aimed at the client, it explains how they can add their own audio files to the unity project, how to arrange the characters in the overarching building and how to add a different building (Appendix 8).

This version of the Sub-application has no further iterations based on user tests, due to time constraints and the specificity of the user's characteristics needed to effectively test the application. Instead the findings discussed in Evaluation round 3 were taken as indications of good design practices.

Chapter 6: Conclusion

The goal of this project was to develop a VR application that could be used to familiarize potential renters with a modular-home; as well as to aid in convincing city council members of the added benefit of modular building in industrial heritage. After co-developing and evaluating a proposed application various times, a final prototype was realized that could serve the first purpose. The prototype allows potential renters to view and personalize a modular home in VR in an interactive and intuitive manner.

A sub-application to serve the second purpose was developed, based on knowledge gathered during the evaluation of the main application. This prototype lets city council members explore the box-in-box concept in VR in a simplified manner. By teleporting through the building and listening to realtor's explanations about various aspects of the box-in-box project; city council members can still get an immersive experience in this prototype. The difference is that this prototype requires less learning and the use of only one controller, as opposed to the main application. This sub-application was combined with a guide aimed at real estate agencies, which allows them to create their own semi-guided VR tours for city council members.

To answers RQ1 "How can an intuitive VR application be used to familiarize potential renters with a modular-home?", the main application was evaluated and adapted three times, finally resulting in a SUS score of 93.

To answer RQ2 "How can VR be used to convince city council members of the added benefit of modular building in industrial heritage?" the sub-application was developed based on the knowledge gathered in the main application's evaluation. The sub-application was not separately evaluated however, meaning that no final answer has been found to this research question yet.

To answer SQ1 "In what unique way does VR influence someone's attitude towards a property?" the importance of a sense of presence in VR with regards to real estate was outlined.

SQ2, "How does UI design aid in making a VR application intuitive?", was answered by making an outline of important design practices when creating a UI for VR

SQ3 "What benefit can VR bring to the property selling process that other mediums cannot?" was answered by analyzing related existing software that fit the context of the problem statement from the client. Next to this, it was researched how VR for real estate is applied in practice and which benefits this brings with it.

SQ4 "How open are inexperienced users towards the concept of VR?" was researched in round 2 and 3 of the evaluation phase, where the influences of UI design and a tutorial pamphlet were tested through questionnaires and SUS tests.

Chapter 7: Future work

Both developed prototypes could in theory be combined in a single application, offering users the option to switch between them in a selection menu. Additionally the prototypes could be merged with the works developed by the other Creative Technology student researching this problem statement, to create an even more multifaceted application.

When going off of the user tests, believability and immersion could be further improved by developing an interaction where a finer balance between physics and structure exists. Additionally the implementation of higher detail through materials colors and lights could be implemented for this same purpose. Implementing this detail would require optimization measures or better computer hardware however.

More research could be conducted to look at the effectiveness of applying prototypes, such as the ones developed for this project, in practice. Currently the theorized effectiveness is solely based on literature, anecdotes and small sample user tests where the direct effectiveness at reaching their specified goals was not yet tested.

In future versions the personalization of the homes could be improved, by allowing the users to load in their own furniture before entering the virtual environment. This could improve the feeling of ownership of the home even more.

The usability of the application and the experience of the user would also be improved if they were able to save their layout halfway through the design process. For some of the users the application became tiresome to use after a while, which meant that they had to exit the virtual environment before finishing their design. Giving them the option to later revisit the design would improve user friendliness of the application.

To give more insights in the price of the select furniture pieces and utilities, a ‘total price’ indicator could be added that tracks which objects have been placed in the room, adds all their registered prices up and displays them somewhere in the virtual environment. This would give the user more awareness during the design process and could keep them from placing too many items in the rooms.

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Appendix

1: Innovationhub Salland problem statement

Modulair bouwen in industrieel erfgoed

Inzicht krijgen in modulaire bouwprincipes, te realiseren in industrieel erfgoed met moderne inmeet-tools en visualisatietechnieken

Panden en complexen van industrieel erfgoed zijn aantrekkelijke vestigingsplaatsen, zowel voor creatieve ondernemers als voor de woonmarkt. Diverse bouwprojecten zijn in Nederland al gestart, en geslaagde (her-)ontwikkeltrajecten reeds gerealiseerd.

Twee ondernemers van Innovatiehub Salland, Rob Lenferink en Marten Jansen (Mensink Bouw), willen bij de herontwikkeling van cultureel erfgoed modulaire bouwprincipes introduceren. Het doel is om zo aantrekkelijke woningen te creëren voor starters op de woningmarkt.

Met modulaire bouwprincipes - waarbij grote bouwdelen, en bijbehorende infra als bekabeling en leidingwerk worden voorbereid in de fabriek – is op open bouwplaatsen al veel praktijkervaring opgedaan, zowel bij nieuwbouw als bij grootschalige verbouw-projecten in woonwijken. Om deze principes toe te passen in een culturele erfgoed setting is echter nog het nodige ontwikkel-, experimenteer- en simulatiewerk geboden: montage en afwerking in een vaststaande buitenschil vereisen exact maatwerk, logistieke planning en innovatief materiaalgebruik alsook slim samengestelde functionele (sub-)bouwdelen.

Met inzet van de meest recente gebouw-inmeettools, visualisatietechnieken en VR/AR simulatie-experimenten, hopen de ondernemers snel de juiste keuzen te maken voor een eerste pilotproject om modulaire bouwprincipes daadwerkelijk toe te passen: leren ter plekke. Bij deze innovatieve aanpak wil men van meet af aan samenwerken met jong talent van de Universiteit Twente en Saxion Hogescholen.

Achtergrondinformatie

InnovatiehubSalland is een samenwerking tussen vier bouwtechnische bedrijven in de regio Salland, opgericht in september 2019 om jonge talenten te binden, boeien en behouden voor de Sallandse bouwkolom. De vraag naar jong talent en de ambitie om te vernieuwen in de organisaties, vormen de belangrijkste drijfveer.

Opdracht

De bouwers die aangesloten zijn bij InnovatieHub Salland willen ‘doosvormige’ maar tegelijk ook aantrekkelijke woningen realiseren binnenin Industrieel Erfgoed complexen. De woningen moeten geen student- of tijdelijke woningen worden, maar meerjarig aantrekkelijk zijn voor 'starters' op de woningmarkt. Hoewel maatwerk vereist zal zijn, willen de bouwers zoveel mogelijk bestaande concepten van ‘modulair bouwen’ inzetten bij deze bouwprojecten. Te denken valt aan prefab-wanden met voorzieningen als elektriciteit, kabels en pijpwerk die worden voorbereid in de fabriek en vervolgens op de bouwplaats in elkaar gezet. In conventionele modulaire bouwconcepten wordt buiten gewerkt. Hier gaat om inzetbaarheid van deze technieken in bestaande complexen waarvan de buitenschil vaststaat.

Het realiseren van modulaire bouwprocessen van binnenuit (denk aan een grote kerk of industrieel erfgoed fabrieken en hallen) is mogelijk wanneer meer inzicht wordt verkregen in:

- slim omgaan met de geometrische randvoorwaarden
- de inzet van nieuwe montagetechnieken, - goede logistieke planningen
- de haalbaarheid van nieuwe dimensionering
- oplossingen
- de inzet van nieuwe materialen
- innovatieve oplossingen voor infra (zoals bekabeling en leidingwerk)

Belangrijke randvoorwaarden voor deze interne manier van modulair bouwen zijn:
- aanvoer van de bouwmaterialen door voordeur of (tijdelijke) openingen in de buitenschel,
- beperkte vrijheid van werken voor montage en bouw,
- inpassing van noodzakelijke infra-voorzieningen
- gegarandeerd halen van certificeringen en (energie-)prestatienormen.

De ondernemers hebben de beschikking over de modernste digitale inmeet- en bewerkingsprogramma's. Graag verkennen zij met een studentonderzoeker Creative Technology een aantal cruciale bouw-, montage en afwerkroutes. Zo kunnen goede keuze worden gemaakt voor een eerste praktijkproject waarbij deze modulaire principes daadwerkelijk worden toegepast.

Na een inventarisatie van de randvoorwaarden/programma van eisen, is het de bedoeling dat een eerste reeks experimenten mbv geschikte visualisatietechnieken wordt uitgevoerd. Zo kan inzicht worden verkregen in de werkwijze en haalbaarheid van (een aantal) modulaire bouwprincipes. De inmeettechnologie en computersimulaties van de bouwondernemers vormen daarbij startpunt en uitgangspunt. Zo kunnen de ondernemers zelf 'leren' welke modulaire technieken haalbaar zijn + in welke gebouwen modulair bouwen wel of geen optie is.

2: Interview questions client

Dutch:
Iemand heeft nog nooit (met een controller) gegamed en kent de basis principes van een controller niet, hoe kan deze persoon toch de software gebruiken?

Iemand heeft teveel meubels neergezet of wil de opstelling resetten, wat nu?

Wat als mensen meubels hebben die ze graag mee willen nemen naar deze woningen, is dat dan een optie, en hoe moet dit gecommuniceerd worden?

Wat als iemand in zijn eentje in een van deze woningen is gekomen maar nu met iemand samen wil wonen, is er dan ruimte voor uitbreiding?

Hoe benaderen jullie gemeentes nu om dit project voor te leggen, en waar in dit proces zou de applicatie van pas kunnen komen?

Wat als mensen deze applicatie willen gebruiken maar ver weg wonen?

Voor immersion/een gevoel van aanwezigheid zijn gedetailleerde materialen niet nodig in VR, is dit iets wat jullie toch graag zouden zien? Waarom?

English:

Someone has never gamed (with a controller) before and doesn't know the basic workings of a controller, how would this person still be able to use the software?

Someone placed to many objects and wants to remove them or reset the scene, how should this be implemented?

What if people already own furniture that they want to take with them to this home, is this a possibility, and how should this be communicated?

What if someone started living here by themselves but wants to live together with someone else now, is there room for expansion?

How do you currently approach the city councils to tell them about this project, and where in the process could the application be of use?

What if people want to use the application but live (too) far away?

For immersion and a feeling of presence a high level of detail in the virtual environment is not necessary, is a level of detail something you would still like to see? Why?

3: Information Brochure for user testing

Informatieblad voor onderzoek 'Developing an immersive VR tool for modular housing in industrial heritage to inform potential renters and government officials'

Context
Innovatiehub Salland (een samenwerking van verschillende bouwbedrijven) gaat modulaire woningen voor starters bouwen in industrieel erfgoed. Om deze woningen te presenteren aan potentiële huurders en ambtenaren is er een virtual reality (VR) applicatie ontwikkeld die de gebruiker een rondleiding geeft, of zelf een interactief kijkje laat nemen in deze woningen voordat ze echt gebouwd zijn.

Doel van het onderzoek
Het doel van dit onderzoek is om de huidige graad van gebruiksvriendelijkheid in het prototype vast te stellen en om vast te stellen of de applicatie intuïtief genoeg is om te gebruiken zonder voorafgaande uitleg. De verzamelde data zal gebruikt worden om de applicatie verder te ontwikkelen en zal ook geanonimiseerd gepubliceerd worden in mijn bachelor thesis.
Tijdens het onderzoek zult u een-voor-een 6 taken krijgen die in de digitale woning uitgevoerd moeten worden. De taken zullen bestaan uit simpele alledaagse handelingen.

Hoe gaan we te werk?
Dit onderzoek wordt geleid door Jelle Smith.
U neemt deel aan een onderzoek waarbij we informatie zullen vergaren doormiddel van observatie tijdens het gebruik van het prototype; en een schriftelijke questionnaire naderhand. De observaties zullen bestaan uit schriftelijke notities van: Uw opmerkingen tijdens het uitvoeren van de taken; duidelijk zichtbare frustraties; eventueel benodigde hints; opmerkelijke struikelpunten en benodigde tijd om de taken te voltooien.

Vergoeding
U ontvangt voor deelname aan dit onderzoek een vergoeding van een snack als waardering.

Vertrouwelijkheid van gegevens
Wij doen er alles aan uw privacy zo goed mogelijk te beschermen. Er wordt op geen enkele wijze vertrouwelijke informatie of persoonsgegevens van of over u verzameld of naar buiten gebracht, waardoor iemand u zou kunnen herkennen.
Voordat onze onderzoeksgegevens naar buiten gebracht worden, worden uw gegevens zoveel mogelijk geanonimiseerd waar nog nodig zou kunnen zijn.

In de uiteindelijke publicatie zullen alleen pseudoniemen gebruikt worden in de vorm van "participant 1, participant 2, participant 3 etc…). De formulieren en andere documenten die in het kader van deze studie worden gemaakt of verzameld, worden opgeslagen op een beveiligde locatie bij de Universiteit Twente en op de beveiligde (versleutelde) gegevensdragers van de onderzoekers (google drive, laptop opslag en beveiligde harde schijf).
De onderzoeksgegevens worden bewaard voor een periode van 10 jaar. Uiterlijk na het verstrijken van deze termijn zullen de gegevens worden verwijderd of worden geanonimiseerd zodat ze niet meer te herleiden zijn tot een persoon.

De onderzoeksgegevens worden indien nodig (bijvoorbeeld voor een controle op wetenschappelijke integriteit) en alleen in anonieme vorm ter beschikking gesteld aan personen buiten de onderzoeksgroep.

Tot slot is dit onderzoek beoordeeld en goedgekeurd door de ethische commissie van de onderzoeksinstantie EEMCS-HMI.

Vrijwilligheid
Deelname aan dit onderzoek is geheel vrijwillig. U kunt als deelnemer uw medewerking aan het onderzoek te allen tijde stoppen, of weigeren dat uw gegevens voor het onderzoek mogen worden gebruikt, zonder opgaaf van redenen. Het stopzetten van deelname heeft geen nadelige gevolgen voor u of de eventueel reeds ontvangen vergoeding.

U kunt er ten alle tijden voor kiezen om de deelname aan het Virtual Reality deel van het onderzoek vroegtijdig te staken en meteen over te gaan op de questionnaire. De observaties tot dat punt zullen dan, mits u daar toestemming voor verstrekt, gebruikt worden in het onderzoek. Als u tijdens het onderzoek besluit om uw medewerking volledig te staken, zullen de gegevens die u reeds hebt verstrekt tot het moment van intrekking van de toestemming niet in het onderzoek gebruikt worden.

Mocht u symptomen van wagenziekte ervaren of hulp nodig hebben tijdens het experiment, dan is het ten alle tijden toegestaan om de headset te verwijderen en naar wens het experiment later te hervatten of af te lassen. Daarnaast zal de onderzoeksleider met enige regelmaat informeren of u een van deze symptomen ervaart, en zal hij zijn best doen om zichtbare tekens van symptomen tijdig te signaleren en daarop te handelen.

Wilt u stoppen met het onderzoek, of heeft u vragen en/of klachten? Neem dan contact op met de onderzoeksleider:
Jelle Smith – verwijderd voor privacy redenen

Of de afstudeer begeleider:
Job Zwiers – verwijderd voor privacy redenen

Voor bezwaren met betrekking tot de opzet en of uitvoering van het onderzoek kunt u zich ook wenden tot de Secretaris van de Ethische Commissie van Computer & Information Science ethicscommittee-cis@utwente.nl. Dit onderzoek wordt uitgevoerd vanuit de Universiteit Twente, faculteit Electrical Engineering, Mathematics and Computer Science (EEMCS). Indien u specifieke vragen hebt over de omgang met persoonsgegevens kun u deze ook richten aan de Functionaris Gegevensbescherming van de UT door een mail te sturen naar dpo@utwente.nl.

Tot slot heeft u het recht een verzoek tot inzage, wijziging, verwijdering of aanpassing van uw gegevens te doen bij de Onderzoeksleider.

Aanvullende informatie:
Om rekening te houden met de corona maatregelen wordt de VR headset voor elk gebruik gedesinfecteerd en contactloos overhandigd, om het risico op besmetting te verlagen.
Bij het gebruiken van VR applicaties ondervinden sommige gebruikers een vorm van wagenziekte, wetenschappelijk onderbouwde methodes om dit zoveel mogelijk te voorkomen zijn toegepast in deze applicatie. Als u toch besluit om nu of later te stoppen met het onderzoek vanwege deze reden is dat volledig toegestaan en hoeft u hier geen nadere verklaring voor te geven, uw compensatie zal dan ook niet vervallen.

4: Informed consent form for user testing

Toestemmingsformulier voor onderzoek met betrekking tot "Developing an immersive VR tool for modular housing in industrial heritage to inform potential renters and government officials."

Het doel van dit onderzoek is om de huidige graad van gebruiksvriendelijkheid in het prototype te bepalen en om vast te stellen of de applicatie intuïtief genoeg is om te gebruiken zonder voorafgaande uitleg.

Door dit toestemmingsformulier te ondertekenen erken ik het volgende:

1. Ik ben voldoende geïnformeerd over het onderzoek door middel van een separaat informatieblad. Ik heb het informatieblad gelezen en heb daarna de mogelijkheid gehad vragen te kunnen stellen. Deze vragen zijn voldoende beantwoord.
2. Ik neem vrijwillig deel aan dit onderzoek. Er is geen expliciete of impliciete dwang voor mij om aan dit onderzoek deel te nemen. Het is mij duidelijk dat ik deelname aan het onderzoek op elk moment, zonder opgaaf van reden, kan beëindigen. Ik hoef een vraag niet te beantwoorden als ik dat niet wil.

Naast het bovenstaande is het hieronder mogelijk voor verschillende onderdelen van het onderzoek specifiek toestemming te geven. U kunt er per onderdeel voor kiezen wel of geen toestemming te geven. Indien u voor alles toestemming wil geven, is dat mogelijk via de aanvinkbox onderaan de stellingen.

	JA	NEE
3. Ik geef toestemming om de gegevens die gedurende het onderzoek bij mij worden verzameld te verwerken zoals is opgenomen in het bijgevoegde informatieblad.	□	□
4. Ik geef toestemming om mijn antwoorden anoniem te gebruiken in de onderzoekspublicaties.	□	□
5. Ik geef toestemming voor alles dat hierboven beschreven staat.	□	

Naam Deelnemer: Naam Onderzoeker: Jelle Smith

Handtekening: Handtekening:

Datum: Datum:

5: Questionnaire for user testing

VR applicatie voor doos-in-doos project

Het doel van dit onderzoek is om de huidige graad van gebruiksvriendelijkheid vast te stellen en om vast te stellen of de applicatie intuïtief genoeg is om te gebruiken zonder voorafgaande uitleg.
De verzamelde data zal gebruikt worden om de applicatie verder te ontwikkelen en zal ook geanonimiseerd gepubliceerd worden in mijn bachelor thesis.

Deze vragenlijst bestaat uit drie secties van 3 tot 4 open en gesloten vragen en een SUS test (System Usability Scale) van 10 gesloten vragen.

Open vragen mogen ook beantwoord worden met steekwoorden of korte zinnen.

Besturing en interactie

Hoe duidelijk was het hoe de controllers/knoppen gebruikt moesten worden in de applicatie? *

	1	2	3	4	5	
Totaal niet duidelijk	○	○	○	○	○	Helemaal duidelijk

Wat was volgens jou de oorzaak voor deze duidelijkheid/onduidelijkheid in de besturing? *

Jouw antwoord

In hoeverre zou een korte tutorial/uitleg de ervaring voor jou verbeteren? *

	1	2	3	4	5	
Weinig	○	○	○	○	○	Veel

Gebruiksvriendelijkheid

Hoe comfortabel was het om de applicatie te gebruiken? *

	1	2	3	4	5	
niet comfortabel	○	○	○	○	○	comfortabel

Hoelang zou jij deze applicatie aan één stuk door willen gebruiken? *

- ○ 0-5 minuten
- ○ 6-10 minuten
- ○ 11-20 minuten
- ○ 20-30 minuten
- ○ langer dan 30 minuten

Wat zou er aan de applicatie kunnen veranderen om deze tijd te verhogen? *

Jouw antwoord

Heb je nog andere opmerkingen over de gebruiksvriendelijkheid, die niet eerder benoemd zijn?

Jouw antwoord

Gevoel van overtuiging en aanwezigheid

In hoeverre had je het gevoel dat je in een echt huis stond? *

	1	2	3	4	5	
totaal niet	○	○	○	○	○	heel erg

In hoeverre voelden de interacties met meubels realistisch aan? *

	1	2	3	4	5	
niet realistisch	○	○	○	○	○	zeer realistisch

Welke aspecten van de applicatie zorgden er voor dat jij je niet aanwezig voelde in de ruimte?

Jouw antwoord

Welke aspecten van de applicatie zorgden er voor dat jij je wél aanwezig voelde in de ruimte?

Jouw antwoord

SUS test (System Usability Scale)

Ik denk dat ik deze applicatie vaak zou willen gebruiken

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik vond de applicatie onnodig complex

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik vond de applicatie makkelijk te gebruiken

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik denk dat ik hulp nodig zou hebben van een technisch persoon om deze applicatie te kunnen gebruiken

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik vond dat de verschillende functies van deze applicatie goed geïntegreerd waren

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik vond dat er teveel inconsistentie in de applicatie zat

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik kan me voorstellen dat de meeste mensen erg snel zouden leren hoe deze applicatie werkt

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik vond de applicatie erg lastig te hanteren

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik voelde mij erg zelfverzekerd in het gebruik van de applicatie

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

Ik moest erg veel dingen leren voordat ik kon beginnen met het gebruiken van de applicatie

	1	2	3	4	5	
Helemaal mee oneens	○	○	○	○	○	Helemaal mee eens

6.1: Questionnaire results

Hoe duidelijk was het hoe de controllers/ knoppen gebruikt moesten worden in de	Wat was volgens jou de oorzaak voor deze duidelijkheid/onduidelijkheid in de besturing?
4	Er waren verschillende mogelijkheden om dingen te veranderen en aan te passen,
5	dit zorgt ervoor dat het hoe dan ook zal lukken om de controls te beheersen
3	Voor de eerste keer dit gebruikt en er stond niet letterlijk bij welke knop ik waarvoor moest gebruiken.
2	veel knopjes en je ziet enkel je handen wanneer je de vr-bril niet op hebt
3,5	
5	Intuïtief, op een vergelijkbare manier als een touchscreen
5	Intuïtieve besturing
5	Prachtige folder
4	Kwam dingen tegen waarvan ik niet wist dat ze bestonden
4,75	

In hoeverre zou een korte tutorial/uitleg de ervaring voor jou verbeteren?	Hoe comfortabel was het om de applicatie te gebruiken?	Hoelang zou jij deze applicatie aan één stuk door willen gebruiken?
4	5	langer dan 30 minuten
4	4	0-5 minuten
5	4	11-20 minuten
5	4	6-10 minuten
4,5	4,25	
		13,75
4	5	20-30 minuten
4	5	20-30 minuten
4	5	20-30 minuten
5	4	11-20 minuten
4,25	4,75	15

Wat zou er aan de applicatie kunnen veranderen om deze tijd te verhogen?	Heb je nog andere opmerkingen over de gebruiksvriendelijkheid, die niet eerder benoemd zijn?
Misschien als je textures kan toevoegen dat het iets realistischer word waardoor het ook leuker is om je huisje in te richten qua styling. ook dat je bijvoorbeeld de muren een kleurtje kan geven.	
Als het je het kan combineren met wat je uiteindelijk ook echt gaat betalen dan ga je er critischer naar kijken en dan spendeer je ook wat meer tijd in de applicatie.	Ik vind het vreemd dat je items kan schalen. En dat je ze door de grond en muren kan bewegen.
Een nog 'echter' gevoel creeeren	Nee geen opmerkingen
meer customization keuzes (behang, vloeren, apparatuur, meubel kleurtjes)	als uitleg eventueel gebruik maken van gestures in-game
Wellicht een saving feature	
Meer meubels, groter huis	Schermen met meubels hingen op een goede plek
Minder op bedden glitchen	Af en toe moeite met objecten uit menu selecteren. Liever hele box als selection
Wat meer detail in het huis	

In hoeverre had je het gevoel dat je in een echt huis stond?	In hoeverre voelden de interacties met meubels realistisch aan?
4	3
4	2
2	3
5	1
3,75	2,25
5	4
5	2
4	3
4	3
4,5	3

Welke aspecten van de applicatie zorgden er voor dat jij je niet aanwezig voelde in de ruimte?	Welke aspecten van de applicatie zorgden er voor dat jij je wél aanwezig voelde in de ruimte?
qua texturen op de muur kan nog wat verbetering worden toegepast	qua bewegen en schaal is het top en realistisch
Het niet volledig realisitische idee van dat je meubels uit een menu kan halen en deze kan schalen naar verschillende grootes.	Het ziet er wel uit als een huis waar je in kan rond bewegen
Het voelde niet als een echt huis en je zag maar een klein deel van de omgeving. Normaal zie je in een opslag veel meer zonder VR-bril.	Door de meubels en de verschillende kamers.
geen feedback (vibraties wanneer in contact komen met de structuur van het huis), geen texturen aanwezig in het huis (afgezien van de keuzes van meubels die gemaakt kunnen worden)	De realistische meubels
deuren niet interactief	juiste schaal
Gebrek aan ruimte in het echt	
Enig glitchen. Objecten clippen niet aan vloer	VR
Detail ontbrak, vooral buiten het huis	Omdat het in VR was

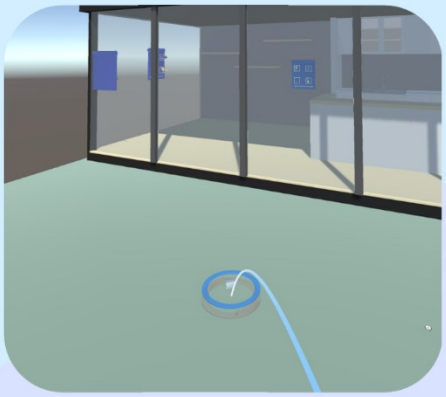
6.2 System Usability Score results

Ik denk dat ik deze applicatie vaak zou willen gebruiken	Ik vond de applicatie onnodig complex	Ik vond de applicatie makkelijk te gebruiken	Ik denk dat ik hulp nodig zou hebben van een technisch persoon om deze applicatie te kunnen gebruiken
5	2	5	2
2	1	4	1
3	1	4	2
3	2	4	2
3,25	1,5	4,25	1,75
3,25	4,5	4,25	4,25
5	1	5	1
5	1	5	2
5	1	4	1
2	1	5	1
4,25	1	4,75	1,25
4,25	5	4,75	4,75

Ik vond dat de verschillende functies van deze applicatie goed geïntegreerd waren	Ik vond dat er teveel inconsistentie in de applicatie zat	Ik kan me voorstellen dat de meeste mensen erg snel zouden leren hoe deze applicatie werkt	Ik vond de applicatie erg lastig te hanteren
4	2	4	2
4	1	4	1
4	2	5	2
3	2	2	2
3,75	1,75	3,75	1,75
3,75	4,25	3,75	4,25
5	1	4	1
5	1	4	1
5		4	1
3	1	4	1
4,5	1	4	1
4,5	5	4	5

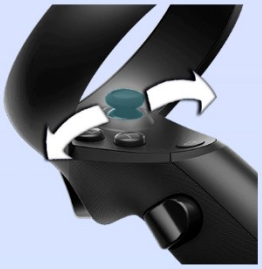
Ik voelde mij erg zelfverzekerd in het gebruik van de applicatie	Ik moest erg veel dingen leren voordat ik kon beginnen met het gebruiken van de applicatie	
4	2	
4	4	
4	2	
5	2	
4,25	2,5	
4,25	3,5	80
4	1	
5	2	
5	1	
5	2	
4,75	1,5	
4,75	4,5	93

7: Tutorial pamphlet



Press joystick forward
to teleport

Pull joystick backward
to take a step back



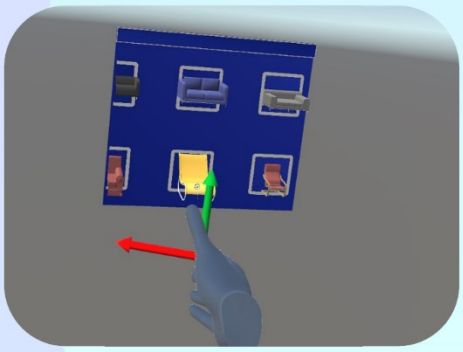
Push joystick left/right
to make a turn

It is possible to move through the virtual-environment by moving in real life.

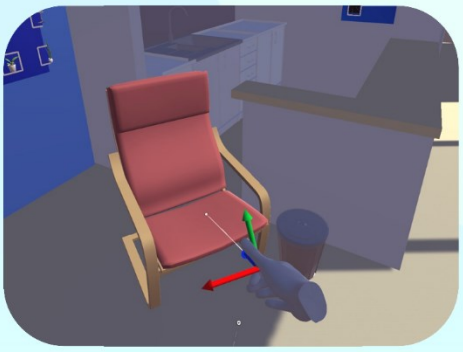
Pay attention to the guardian borders
to ensure safe usage when doing so.

To interact with the virtual environment, press the trigger button on the back of either controller with your pointer finger.

All interactions below use this button to spawn, grab, manipulate or delete various objects and pieces of furniture.

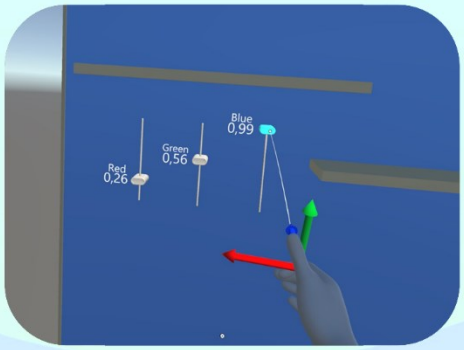


Click an object from any list to spawn it in the room, or swipe through the list to view options.



Move an object by grabbing it and dragging to desired location, delete by dragging it to the bin.

While holding an object with both hands, move hands closer/further apart to resize it, or turn hands to rotate it.



To change the color of the walls, move the sliders to alter the RGB values.

Step 1:

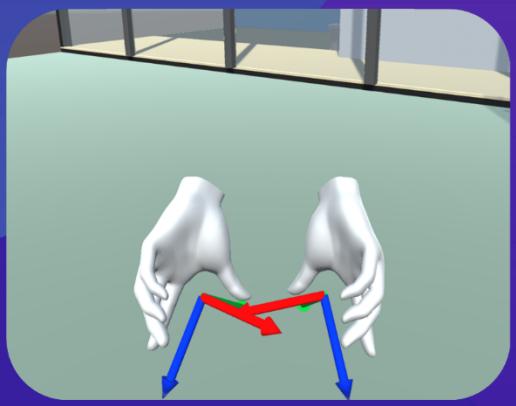
Place the controllers on a surface in front of you. the X/Y controller on the left and B/A on the right.

Step 2:

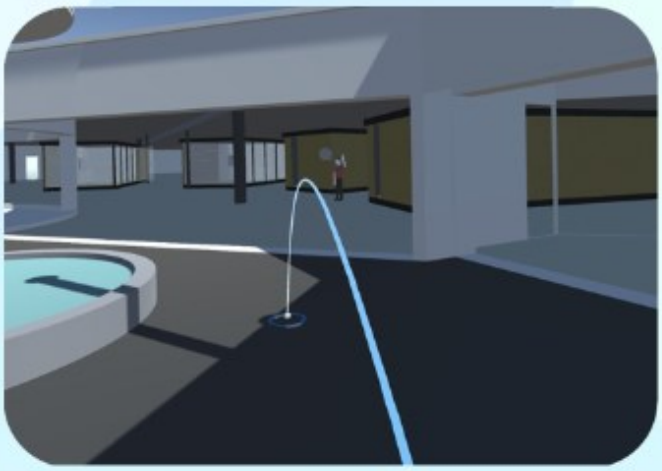
Put the headset on your head and turn the knob on the back till tightened, it shouldn't shake when moving your head.

Step 3:

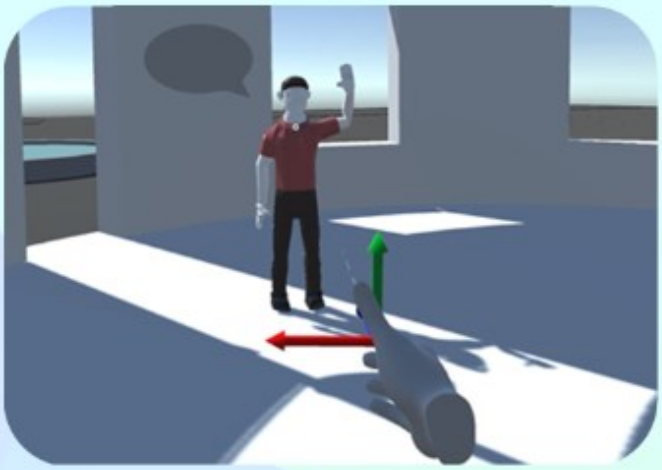
The virtual environment should now be visible, pick up the controllers and you are ready to go!.



7.1 Adapted tutorial pamphlet page 3 for sub-application



You can encounter various characters in the building, teleport to them to see what they can tell you.

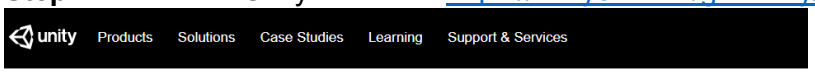


When you reach their location, point your controller at them and they will give you some information about their part of the building.

8: Unity tutorial for client

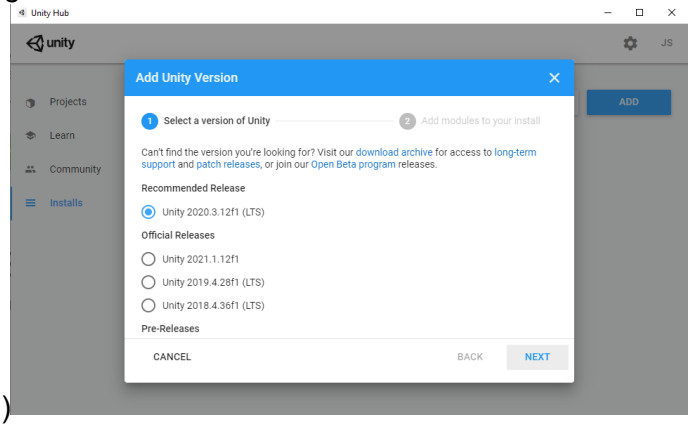
Getting started

Step 1: download Unity Hub from https://unity3d.com/get-unity/download

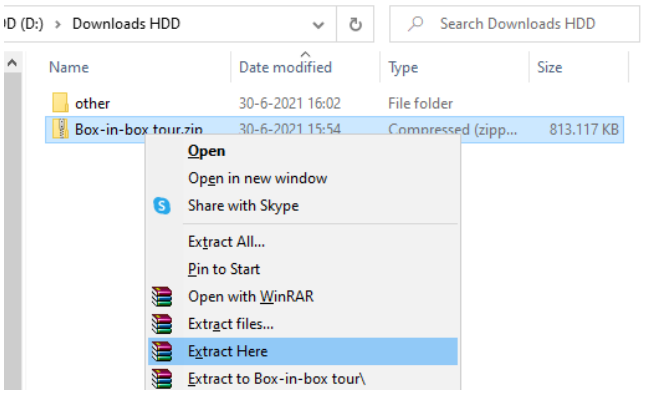


Start UnityHubSetup.exe and follow the installation procedure.

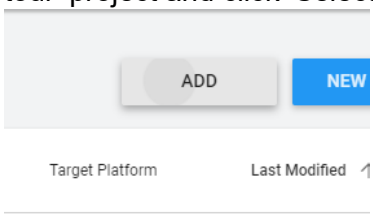
Step 2: navigate to 'Installs' and download the recommended release (Unity 2020.3.10f1)

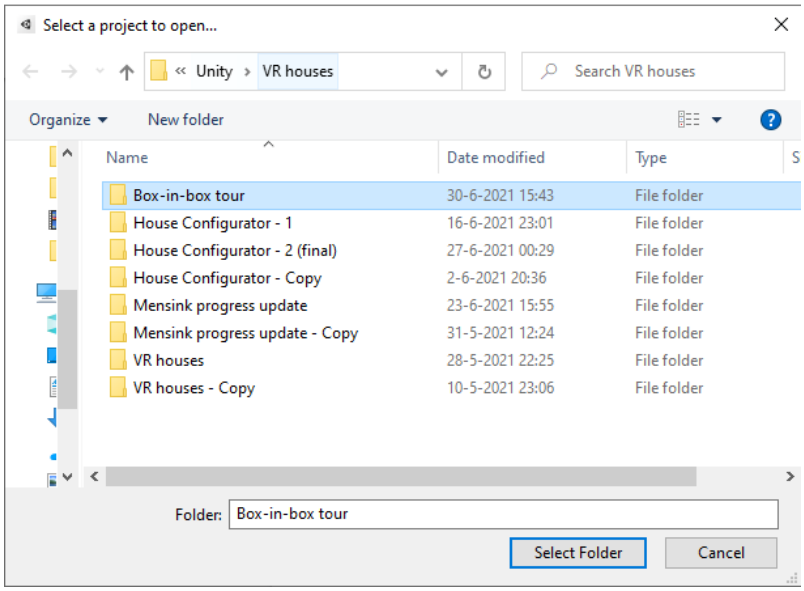


Step 3: Download the 'Box-in-box tour' unity project here. And extract it

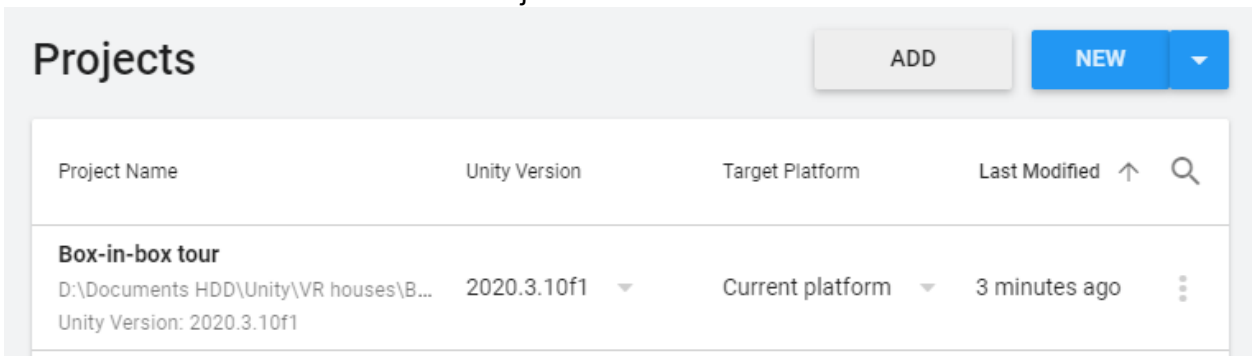


Step 4: Click the add button in the Unity Hub 'Projects' window, locate the 'Box-in-box tour' project and click 'Select folder'.

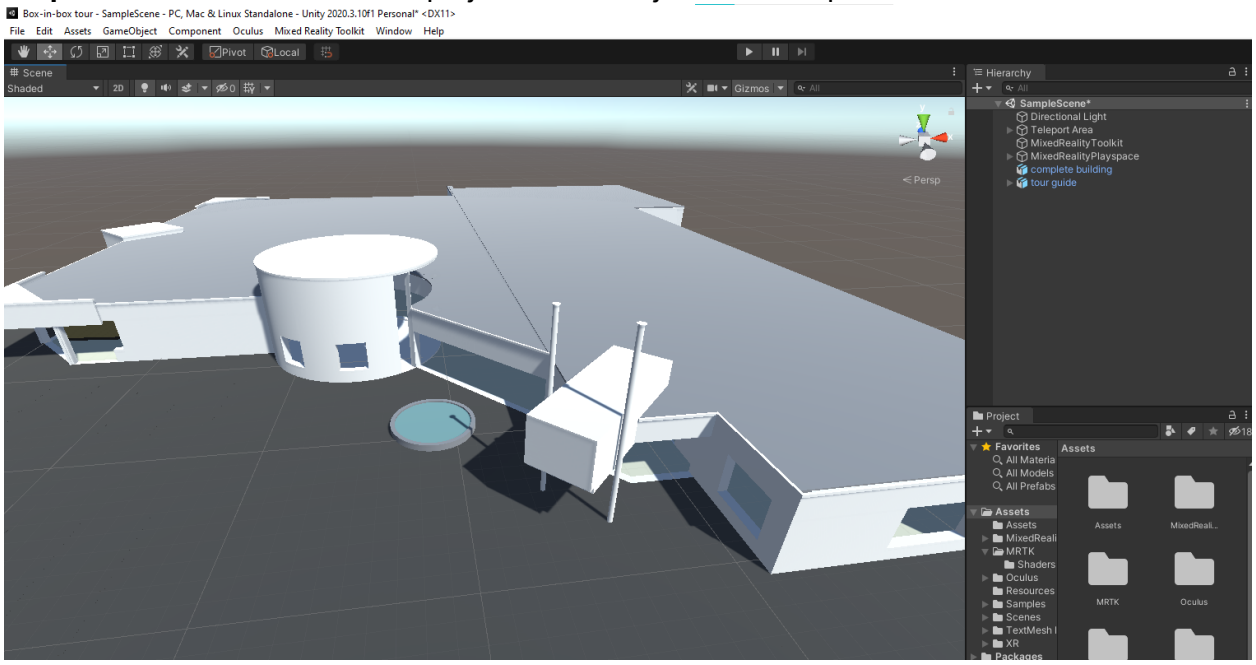




The file should now be visible in the Projects tab



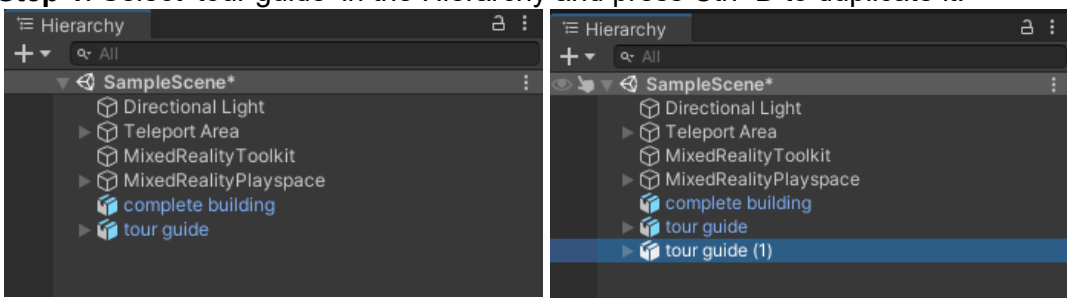
Step 5: Click the Box-inbox tour project in the ‘Projects’ tab to open it.



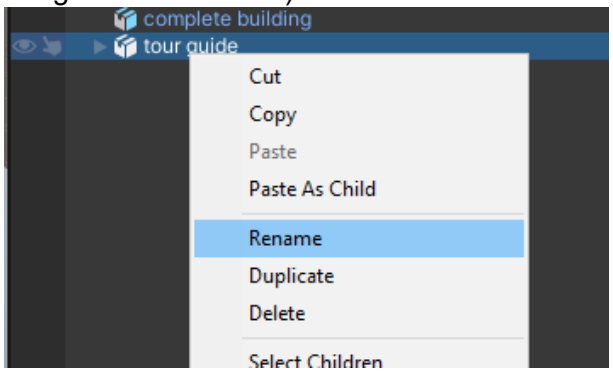
You should now see this scene.

Adding tour guides

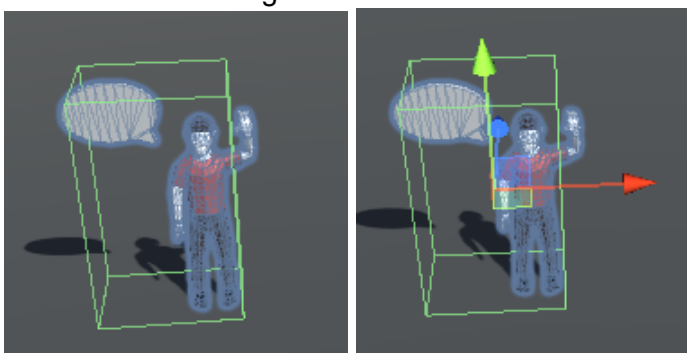
Step 1: Select ‘tour guide’ in the Hierarchy and press Ctrl+D to duplicate it.



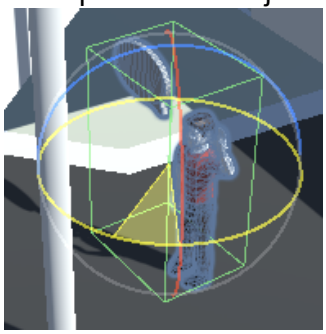
right click and then select ‘rename’ to give the guide an appropriate name (not required but good for overview).



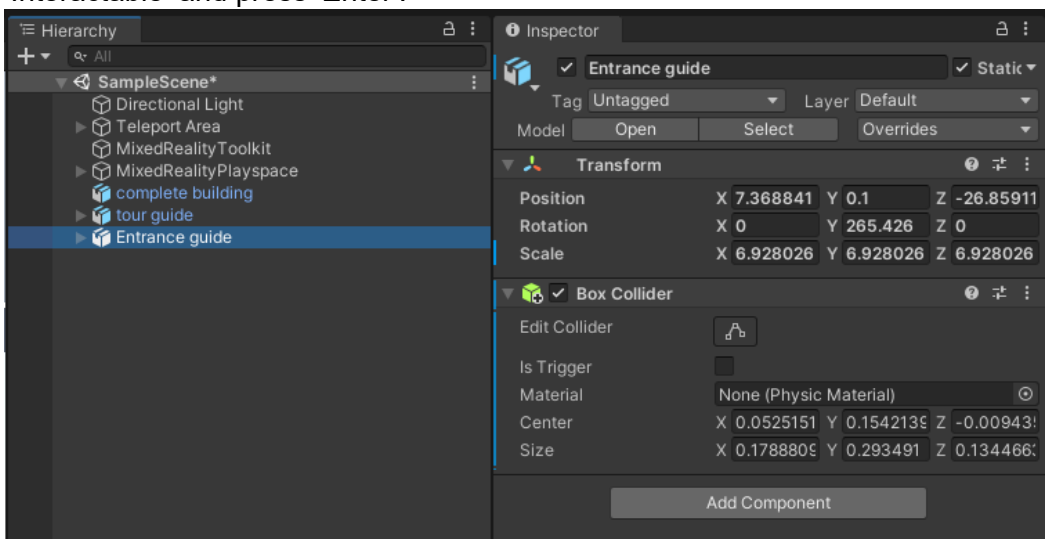
Step 2: Select the new guide in the hierarchy and then press ‘W’ to move it. Use the arrows to move the guide to the desired location.

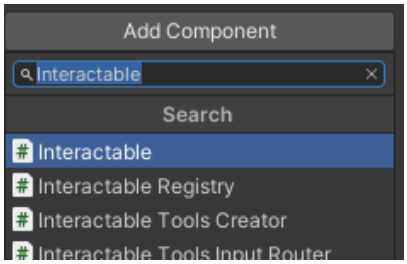


Then press ‘E’ to adjust the rotation by dragging the circles.

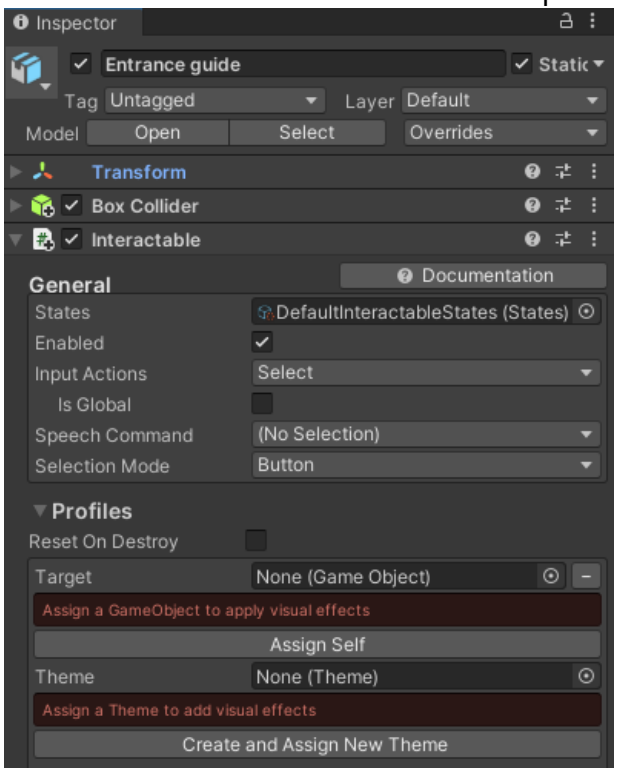


Step 3: With the new guide selected press ‘Add Component’ in the inspector, look for ‘Interactable’ and press ‘Enter’.

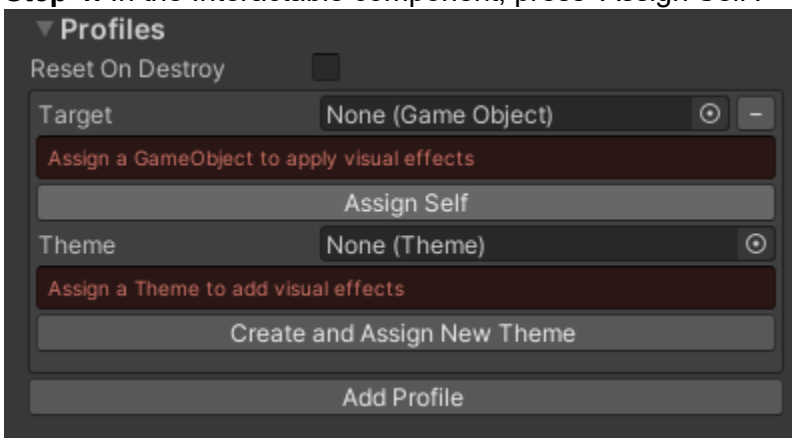




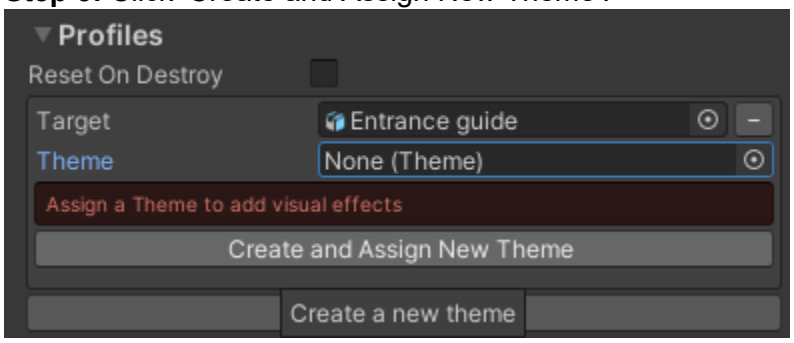
You should now see the Interactable component in the Inspector.



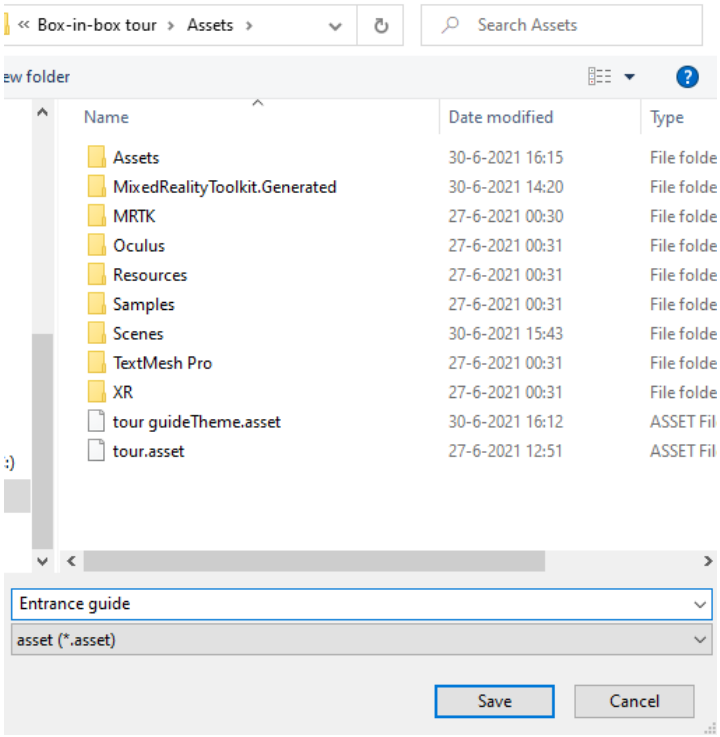
Step 4: In the Interactable component, press ‘Assign Self’.



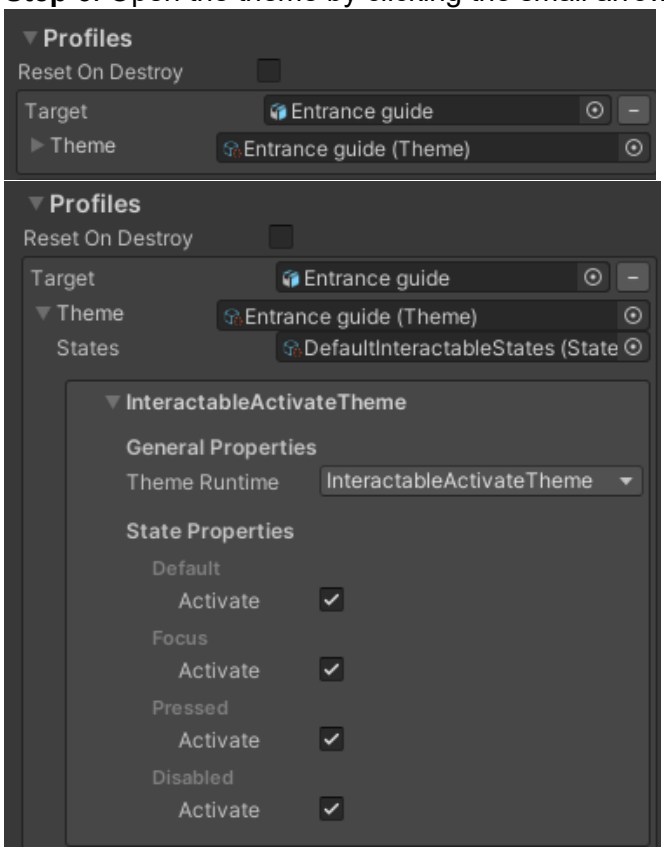
Step 5: Click ‘Create and Assign New Theme’.



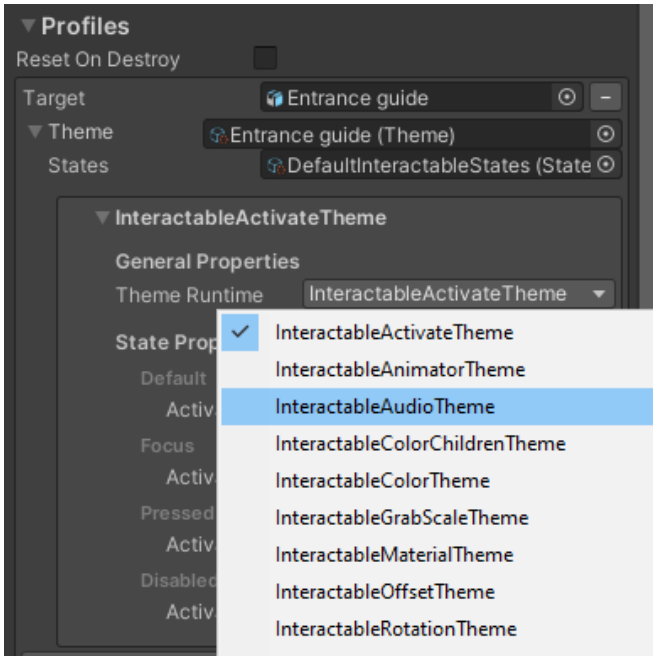
Choose an Appropriate name and press ‘Save’.



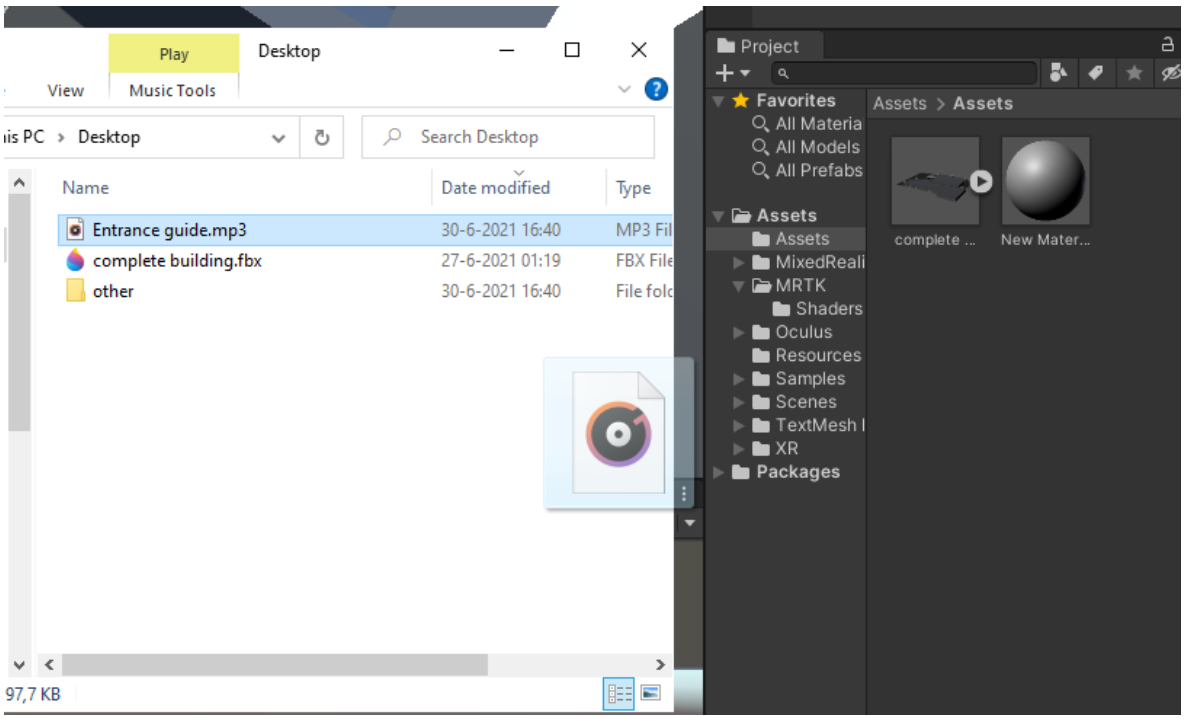
Step 6: Open the theme by clicking the small arrow next to the word ‘Theme’



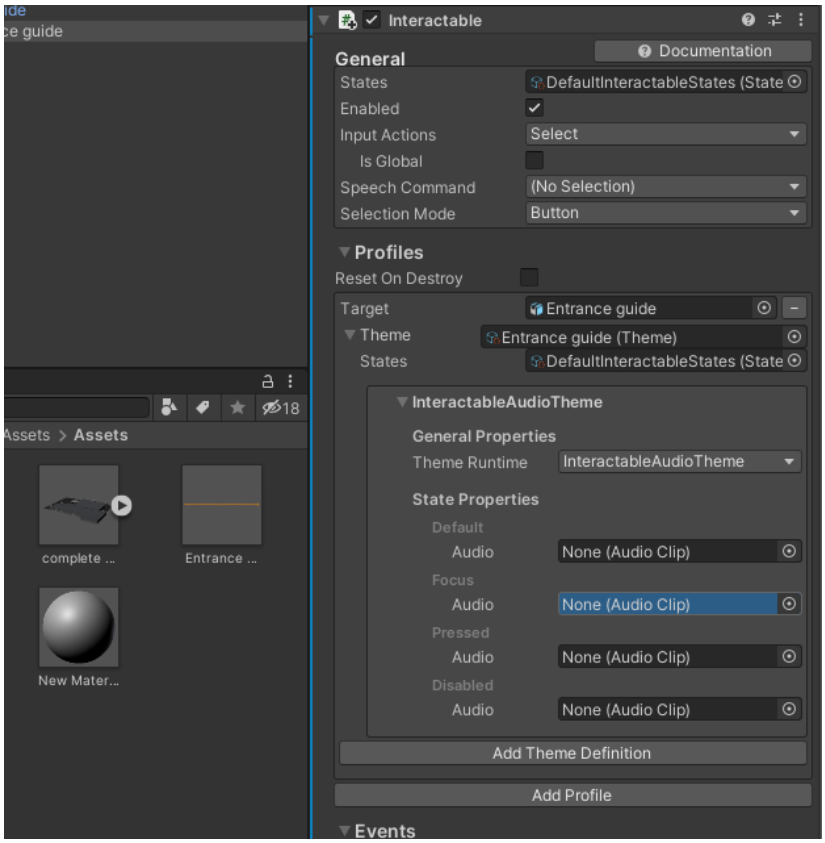
Then click the menu next to ‘Theme Runtime’ and switch it from ‘InteractableActivateTheme’ to ’InteractableAudioTheme’.



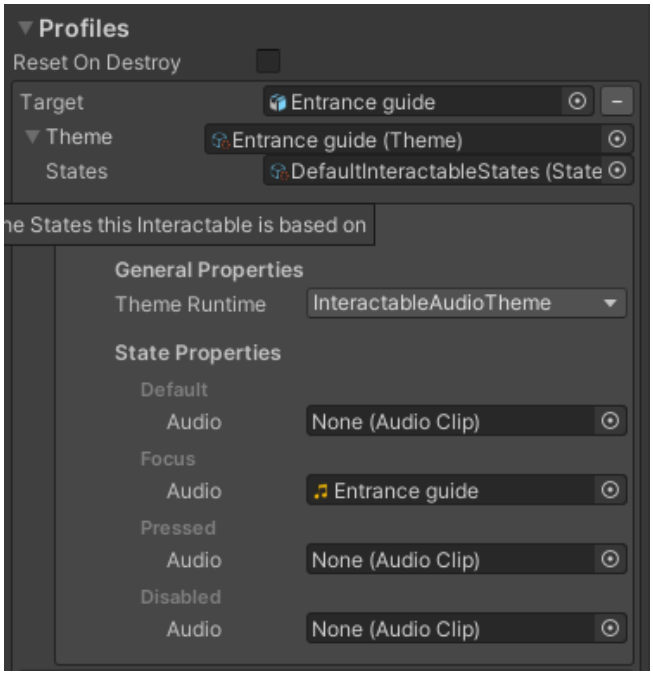
Step 7: Now drag the desired mp3 file for narration into the 'Assets' folder of the Unity project. (These can be recorded using the Voice Recorder built into Windows, make sure to convert them from m4a to mp3 using this website however, otherwise it will not work.)



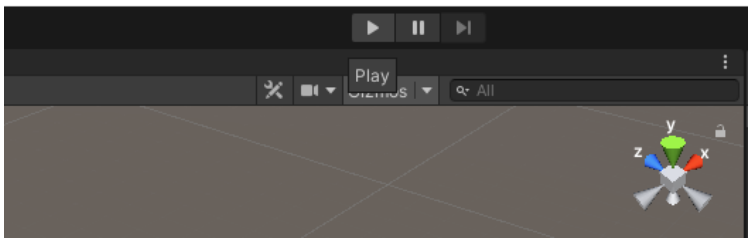
Step 8: Now drag the audio file from the ‘Assets’ folder the to the ‘Focus’/’Audio’ box in the ‘InteractableAudioTheme’.



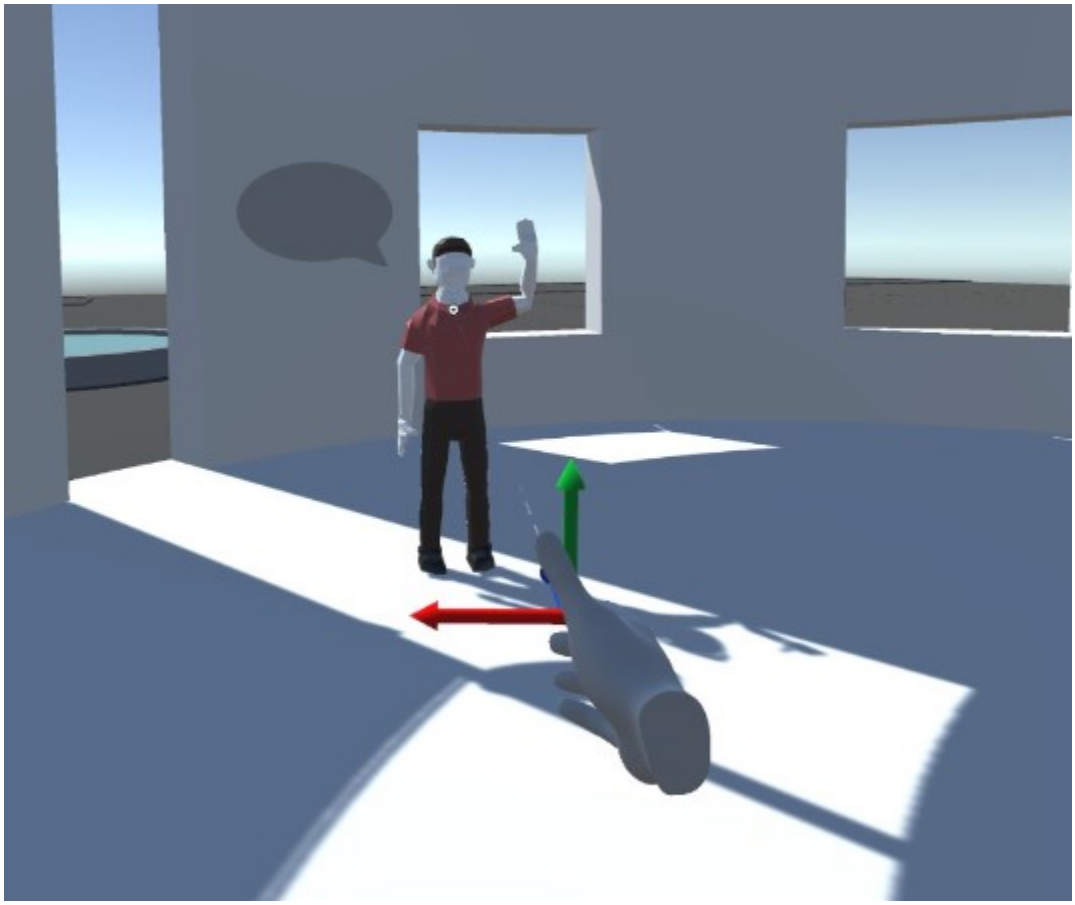
It should now look like this.



Step 9: Now press the play button and test if everything is working



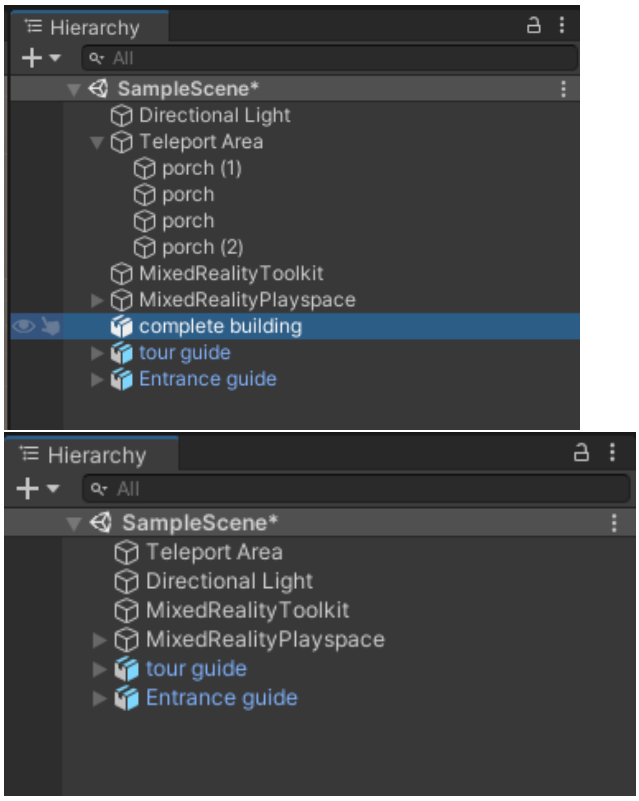
The Audio file should now start playing when you point the controller at the guide character.



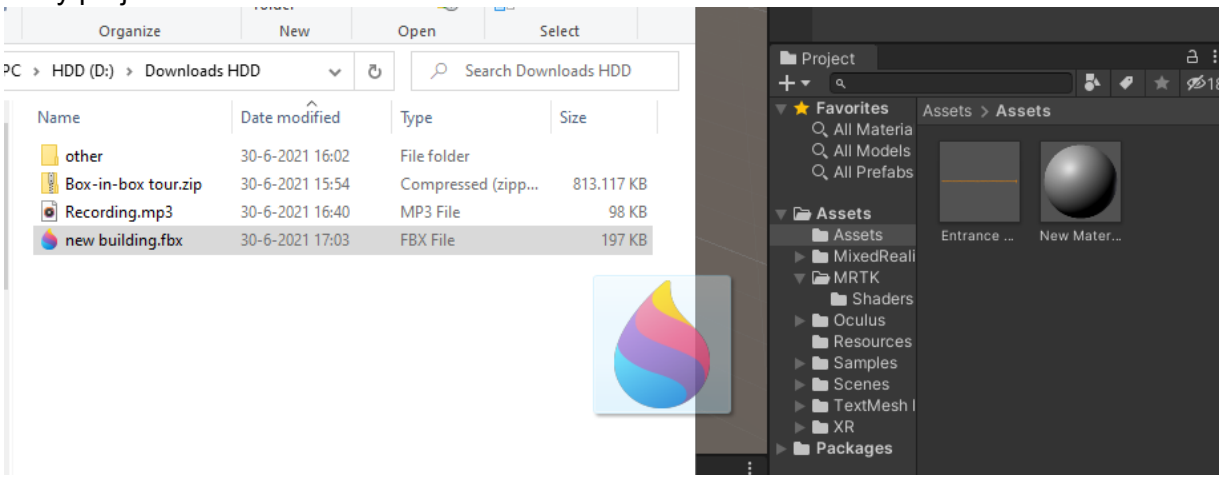
Adding different buildings

To add a new building to the Unity project, it is important to first have a .fbx 3D file of it. You can use this video up to 2:11 as a guide on how to export a .fbx file from ArchiCAD with the textures included.

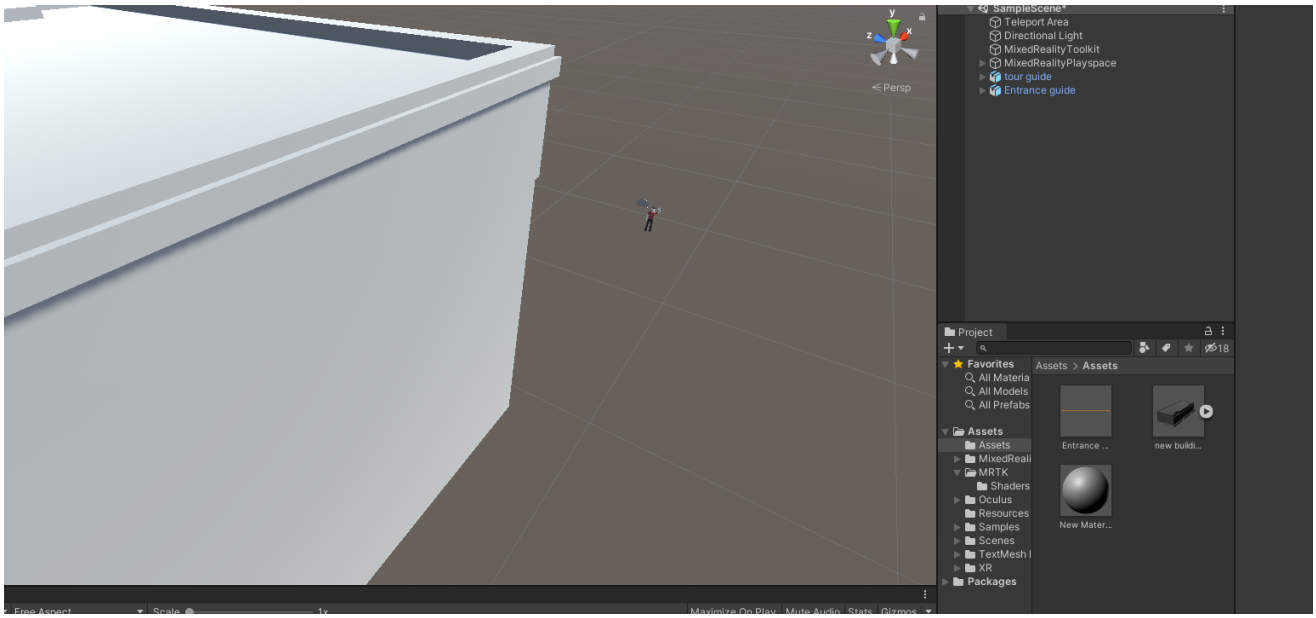
Step 1: First the delete the old building by selecting it in the hierarchy and pressing the 'Delete' button on your keyboard.



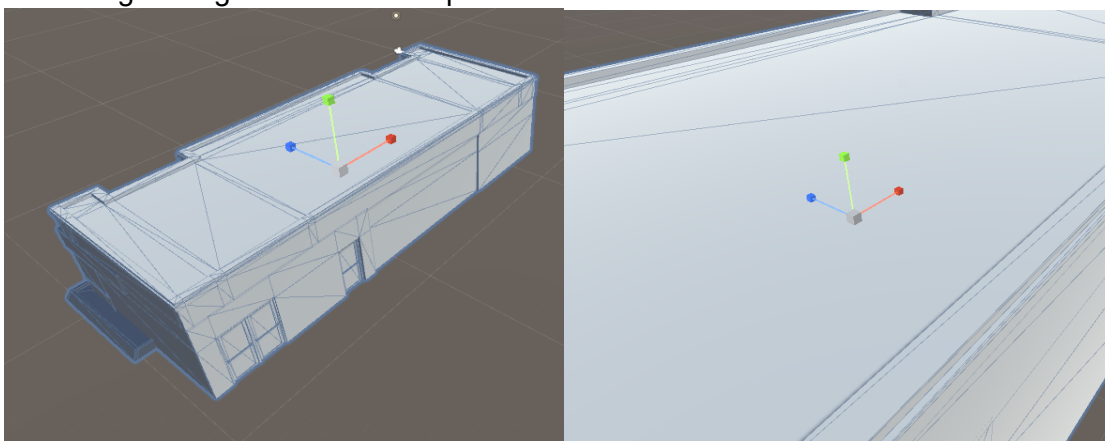
Step 2: Now locate your new building .fbx file and drag it into the 'Assets' folder of the Unity project.



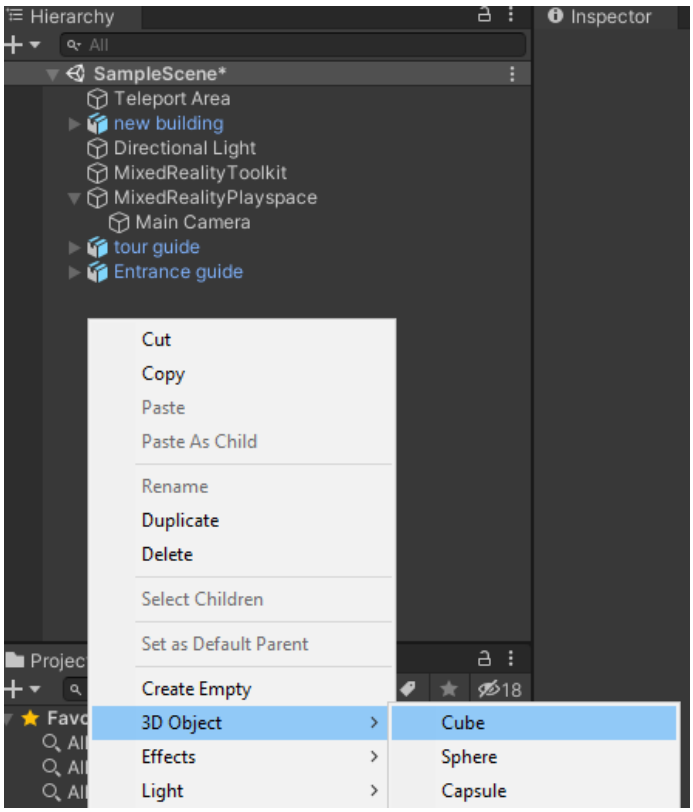
Step 3: Now drag the new building into the Unity scene from the ‘Assets’ folder.



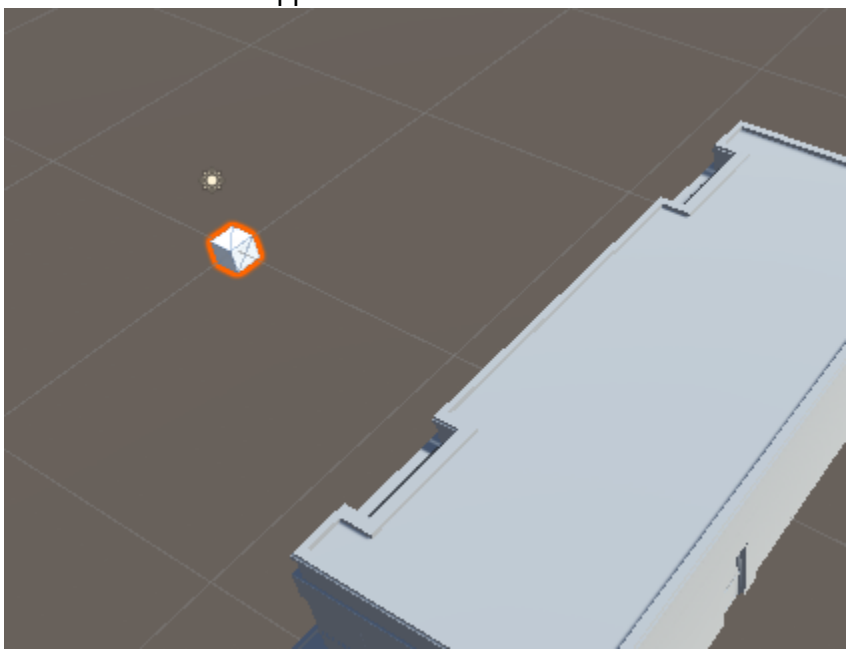
Press ‘R’ and drag the small grey cube to scale the new building correctly. Then use ‘W’ and ‘E’ again to give it the correct position.



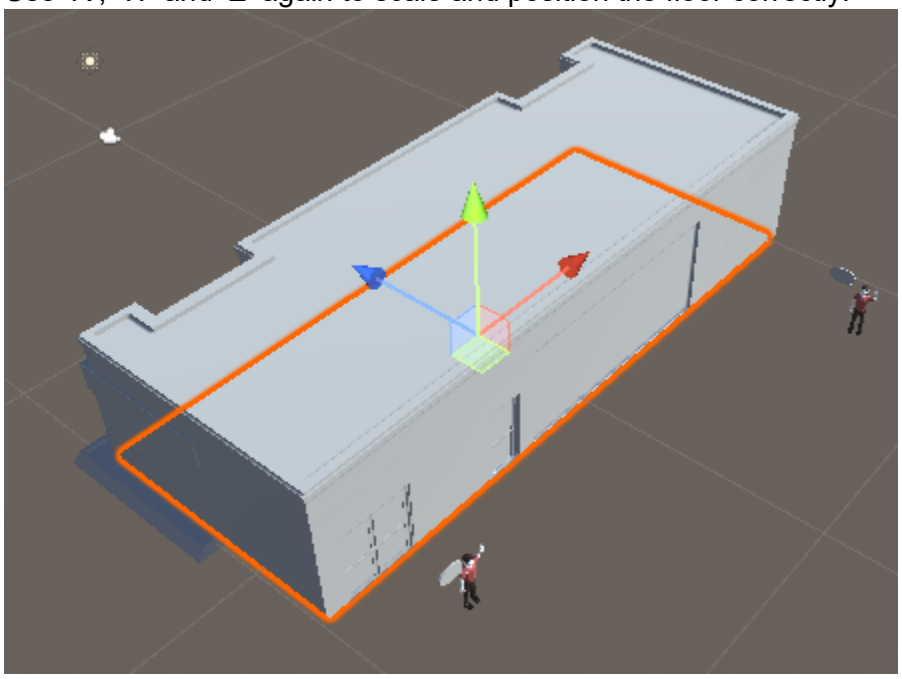
Step 4: In order to be able to use the teleportation in VR, a floor with a 'Box Collider' needs to be added.
'Right-click' in the Hierarchy then press '3D Objects' -> 'Cube'.



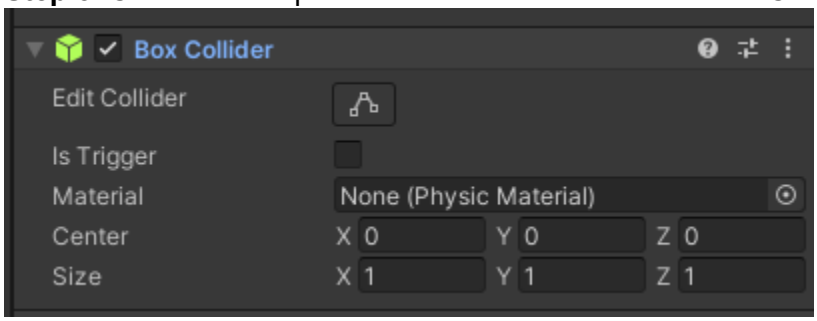
A cube should now appear in the scene.



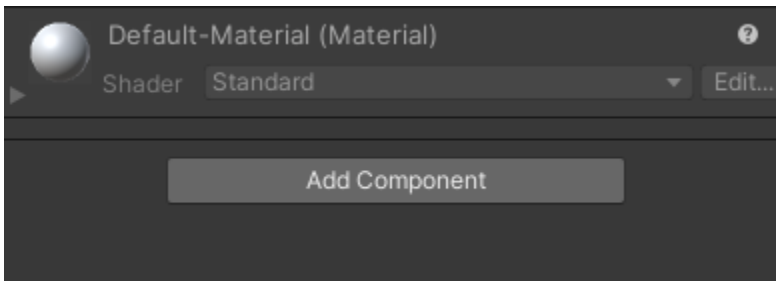
Use ‘R’, ‘W’ and ‘E’ again to scale and position the floor correctly.

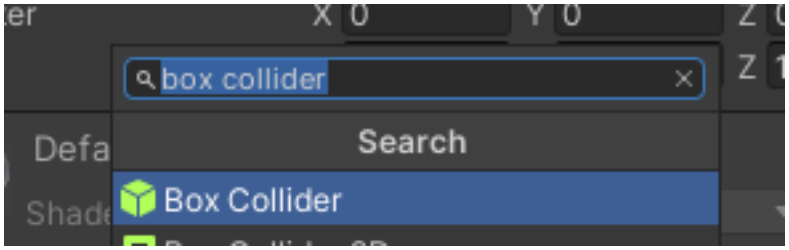


Step 5: Check the ‘Inspector’ to see if the cube has a ‘Box Collider’



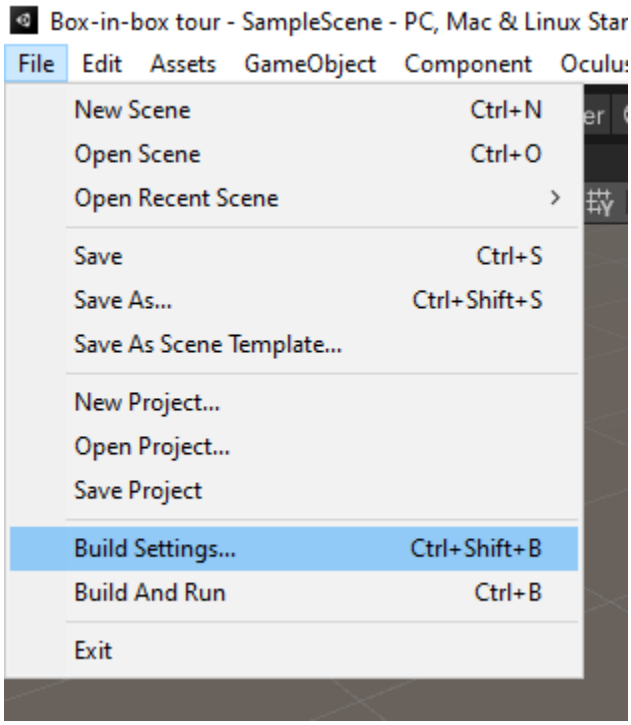
If this is not the case, click ‘Add Component’, search for ‘Box Collider’ and hit ‘Enter’.



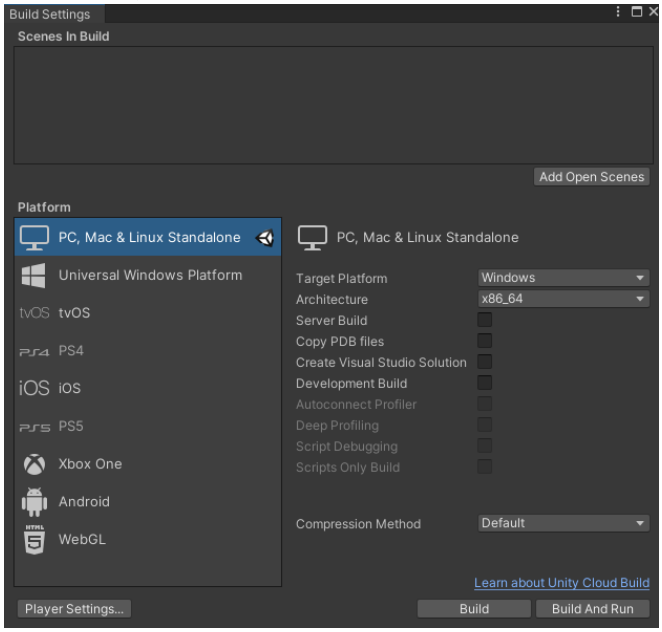


Finalizing

When you are satisfied with your results, go to ‘File’ -> ‘Build Settings…’



Select PC, Mac & Linux Standalone and click ‘Build’.



Unity will now create an executable version of the application that can be played without opening Unity first.