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Jumping for Guided Navigation in Immersive Virtual Environments

Master's Thesis

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Declaration of Authorship

I hereby declare that I have written this thesis without the use of documents and aids other than those stated in the references, that I have mentioned all sources used and that I have cited them correctly according to established academic citation rules, and that the topic or parts of it are not already the object of any work or examination of another study programme.

Date Ramsha Saad Thaniana

Abstract

This is the abstract...

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1 Introduction

Many navigation techniques exist for both Desktop and Immersive Virtual Environments (VE) that define how users moves around these VEs. The goals of navigation are to move towards a target location and orientation to explore the environment. Navigation should facilitate way finding in the VE, which means allowing the user to know where they are, where they will go next and how they will get there. This also means that the user should have a good perception of the VE and path that they took. Navigation techniques have to ensure that there is minimal motion sickness, sufficient environmental awareness which means that while navigating the user knows where they are in an environment compared to where they were before and that it is easy to reach important places in the environment. Two common metaphors for navigation are steering and teleportation.

Steering navigation is a technique where there is continuous movement in a direction indicated either by gaze, pointing or use of a physical device. In some cases an additional action can be added to specify the velocity. With steering navigation spatial awareness is generally good but can cause motion sickness. Teleportation navigation is a target based metaphor for where the goal position is specified discretely by pointing or choosing a location and orientation to be moved towards. This form of navigation minimises motion sickness but results in less environmental awareness as compared to the steering metaphor. Some techniques try to reconcile these two metaphors to minimise motion sickness while still maintaining a good environmental awareness. One example is the jumping metaphor presented by Weissker et al. which *'only allows to teleport to locations in the currently visible part of the scene'* which makes it a short range version of the teleportation metaphor [1].

Navigation techniques can be active such that the user is controlling their own movement; passive such that the user is being automatically moved around the environment; or they can be a mix of active and passive. Navigation techniques can also provide the user with guidance regardless of whether this is active or passive. Guided navigation techniques such as the river analogy presented by Galyean, which guides *'the user's continuous and direct* *input within both space and time allowing a more narrative presentation'* and uses automatic steering for guided navigation allow for the addition of a narrative structure to a VE [2]. In this work we will explore guided navigation using the jumping metaphor instead of a steering one and investigate the benefits of an automatic approach over a user controlled one for a museum setting.

This thesis will discuss work related to navigation techniques and guiding in VEs on Head-Mounted Displays (HMD)s in Chapter **??**.

2 Related Work

As mentioned in Chapter 1, this thesis aims to investigate a technique for automated guided navigation using the jumping metaphor. To understand where the concept for this technique comes from we will take a look at different navigation metaphors for HMDs and see what the advantages of jumping navigation are. We will then see what the purpose of guiding in VEs is and why it can be useful for navigation to be guided. Based on this we will then show the motivation for bringing together jumping and guiding into one navigation technique.

2.1 Navigation

Navigation is the task of moving around and when it comes to 3 Dimensonal (3D) environments it is one of the most common actions that is carried out by users. According to Bowmanm, Kruijff et al.. navigation *'presents challenges such as supporting spatial awareness, providing efficient and comfortable movement between distant locations, and making navigation lightweight so that users can focus on more-important tasks'*. Navigation can be divided into the motor and cognitive components, travel and way finding respectively. Navigation tasks include exploration, search and maneuvering [3]. Our technique will focus on

- Exploration: Navigation with no explicit target for the purpose of investigating the environment.
- Search: Navigation with the intention of going to a target which is known or finding one which is not known.

2.1.1 Quality Factors

Quality factors of a technique are what make it effective. Some of the quality factors that should be taken into consideration before designing and comparing navigation techniques for Immersive VEs as outlined by Bowman, Koller et al. are as follows:

1. Speed (appropriate velocity).
2. Accuracy (proximity to the desired target).
3. Spatial Awareness (the user's implicit knowledge of his position and orientation within the environment during and after travel).
4. Ease of Learning (the ability of a novice user to use the technique).
5. Ease of Use (the complexity or cognitive load of the technique from the user's point of view).
6. Information Gathering (the user's ability to actively obtain information from the environment during travel).
7. Presence (the user's sense of immersion or "being within" the environment) [4].

   In addition to the above there is also a final quality factor:

8. Feeling Well (Avoiding motion sickness).

2.1.2 Travel Metaphors

Travel metaphors can be divided into many categories such as physical movement, viewpoint manipulation, steering, target based and route planning [3]. These different metaphors consider the quality factors as mentioned in Section 2.1.1 to different extents depending on the goal of navigation. When the goal is not travel itself but some other task for which navigation is required, the technique must be more simplistic so as to not take away focus from the task. Hence, two very common metaphors of travel used in such cases are steering and teleportation, which is a form of target based travel.

Steering navigation is continuous movement of the users viewpoint in a specific direction that is controlled by gaze, pointing or a physical device. Velocity may also be varied as an additional action. When steering, as the user is moving continuously through the environment they can see around them and hence, have a good spatial awareness. However, the movement may cause motion sickness as they are physically standing still while their surroundings are moving.

Teleportation, which is also a technique where users are physically standing still, tries to reduce motion sickness by moving directly to a target instead of continuously traveling through the surroundings. However, due to this discrete movement users may miss out on parts of the environment as they go directly to another position and orientation they were in. Therefore, when using teleportation users would have less spatial awareness than if they were steering.

Weissker et al. try to reconcile steering and teleportation metaphors to minimize motion sickness while still getting a similar spatial awareness (or spatial updating) compared to steering, through the jumping metaphor. This is a short-range teleportation technique because it is target based travel to visible parts of the scene. Findings by Weissker et al. were that this technique resulted in *'significantly faster travel times'* as compared to steering but *'similar spatial updating accuracies in both conditions'* for 75% of the participants. It also *'induced significantly less simulator sickness'*. Therefore, the technique can be used in most cases as an alternative for steering, however, there may be some individuals that would have their ability for spatial updating impaired [1].

Navigation techniques using any of these travel metaphors can also have different levels of user control ranging from completely user controlled to fully automatic navigation depending on the use cases.

2.2 Guiding for Navigation

Guiding means to help someone find a target object or location. When speaking of guiding through an environment it would mean showing someone the recommended path through the environment to give them the best experience of it. This would still apply for a VE but requires additional considerations that come with doing anything in Virtual Reality (VR). Guiding can be done for any VR tasks, whether it is navigation, selection, manipulation. However, here we will talk about guiding for navigation in VR.

Guided navigation techniques are motivated by the wish to *'balance the notion of interaction with guidance (telling)'* and to provide a narrative structure to the experience. Galyean presented the River Analogy which is an automatic steering technique for guided navigation and guides *'the user's continuous and direct input within both space and time allowing a more narrative presentation'*. The technique was found to be useful when applied to a VR experience in a museum showing that there are cases where guided interaction for VEs is useful [2].

Another example of guided navigation presented by Freitag et al. uses more passive guiding and simply supplements a users free exploration of the VE. It visualizes the paths a user can follow based on what has already been explored and shows the users what their final location would be if the follow it. A study of this technique showed that it leads to *'improves the knowledge of the scene, leads to a more complete exploration, and is experienced as helpful and easy to use'*. In comparison, during free exploration users *'miss important parts, leading to incorrect or incomplete environment knowledge and a potential negative impact on performance in later tasks.'*, thus showing why guiding could be important when complete environmental knowledge is essential or beneficial [5].

2.3 Conclusion

Sections 2.1 and 2.2 explored research on navigation techniques and why guiding can be useful for interaction in VR, particularly navigation. Based on this research we realized how useful a guiding technique using jumping would be and the considerations that need to be taken when designing such a technique. The motivations for this will be discussed further in Chapter 3 and the considerations when designing it will be further discussed in Chapter 4.

3 Guided Jumping Motivation

In the previous chapter we discussed navigation techniques and why guiding for interaction to show why we decided to design a guided navigation technique using jumping instead of steering. In this chapter we will look at use cases where navigation in a VE is required to further demonstrate the motivation for automated guided jumping for navigation. We will also introduce our research questions for this thesis.

Guiding facilitates exploration of 3D data where it is *'arranged on purpose'* and also applications in which *'the structure and meaning of the 3D data is unknown'*. Beckhaus focused on the former types of applications and tested their CubicalPath system for guided exploration on such applications. This included a Virtual Art Museum [6]. These types of applications can include those where a narrative structure needs to be provided within a VR experience [2] or where complete environmental knowledge is essential [5]. This particularly lends itself to Storytelling in VR and Virtual Tours.

3.1 Storytelling in VR

Storytelling, the art of sharing stories has existed in humanity for millennia. As society has developed so have the ways in which storytelling is accomplished. With the advent of a technological age this storytelling transformed onto screens. Now, in recent times there has been a further breakthrough in storytelling with the advances in VR and the increase in ways of presenting immersive content. As Bucher explains the concept of VR has existed long before the technology itself yet storytelling in VR follows different rules from the traditional stories as the perspective of a story is different in an Immersive Environment [7].

This makes it quite compelling to look into VR techniques that could be used to support this crafting of immersive narratives. Quite a few techniques for designing better VEs for storytelling already exist but the question arises about what the best way of allowing users to move around in these VEs is. We need to ensure that a structure is provided instead of just allowing an *emergent narrative*, which is a story that emerges as a *'product of our interactions and goals as we navigate the experience'*. This is where guiding would come in to *'balance the interaction (exploration) with an ability to guide the user, while at the same time maintaining a sense of pacing or flow through the experience'* [2].

According to Rodriguez et, al. *'Providing effective 3D exploration experiences is particularly relevant when the goal is to allow people to appreciate, understand and interact with intrinsically 3D virtual objects'* [8]. This is a part of storytelling as the narrative structure within the environment may include interacting with 3D objects that are part of it. This is why we believe that storytelling could really benefit from an guided 3D exploration experience. To ensure that a narrative structure is maintained and that users do not end up influencing the narrative structure automatic guiding techniques would be the best, however, there can be ways to give users some choices as well if the experience has room for that.

3.2 Virtual Tours

Similar to storytelling, tours have existed for a long time. People may need tours of any new place they visit or that they become a part of. For example, new students at a school may need a tour of it initially so that they know how to navigate it themselves later on. Tours are also a part of the tourism industry as tourists may take tours of a city they visit or just some important locations in the city. People may also want tours of specific locations such as museums to get more out of visiting those place than they would get if they explored it on their own as they do not have information that a tour guide guiding them through it would have.

As we entered the age of technology we started getting virtual worlds that contain schools, cities, museums, other spaces that are either modeled exactly after some existing physical counterparts or are made from a creator's imagination. Either way this means that now there are virtual spaces just like physical ones that users could benefit from learning about through a tour. This raises the question of what the best way to tour these virtual spaces is. One option would be to have someone physically present where the user is using the VR hardware and guide them verbally. If that is not an option there can be tour guide that could embodied as an avatar and be remotely a part of the VE. Finally an algorithm driven agent could also be a virtual tour guide for users. We felt that this may be useful but wondered about alternatives where we do not want another person or agent in the environment. This made us think about techniques that provide visual guidance and then let the user move themselves following the guiding lines. An example of this is the technique by Freitag et al. that shows possible paths and the target location they would lead to [5]. Besides visual guidance, guiding can also be done automatically such as the River Analogy which was applied to a virtual museum. This is useful when the author of an experience wants to ensure that their intentions of how the tour should be are followed rather than allowing users control on how they navigate [2].

3.3 Conclusion

Based on the use cases presented in the sections 3.1 and 3.2 along with the literature review that led us to believe that the navigation metaphor of jumping is preferable to steering in most cases, we came up with the following goals for the technique to be developed for this thesis:

- Providing a narrative structure to the immersive environment.
- Facilitating acquisition of complete knowledge of the environment.
- Novice friendly interface.
- Reducing motion sickness and disorientation.
- Moving to currently visible part of scene at each point to maintain a visible route.
- Balancing interaction with guiding in an immersive environment.
- Avoiding obstacles, collisions, ghosting and being too close to objects or walls.

Considering these goals of the technique we thought that the following Research Questions were important to keep in mind when developing and evaluating it:

RQ$_1$: How can guided navigation techniques facilitate the acquisition of relevant knowledge of the scene while avoiding motion sickness?

RQ_2: How can we maximize the comprehensibility of a sequence of automated jumps?

RQ_3: Will having guided jumping improve comfort and reduce task load compared to free jumping with visual guidance?

4 Automated Guided Jumping

In this chapter we will start by discussing the interaction design for an automated guided jumping navigation technique that would meet the research questions referenced in section 3.3. This will be followed by details about development of the technique which can be divided into two parts; the setup of an environment and narrative structure for using this technique and development of automated jumping in a way that jumps are comprehensible to users.

4.1 Interaction Design

Looking at the use cases and motivation discussed in Chapter 3 we will first lay out a scenario in which our technique would be used and then go through the interaction design of the technique based on this scenario.

4.1.1 Scenario

We developed our automated guided jumping navigation technique for a virtual tour of an indoor space which a user can do alone without a tour guide. There is potential to think of how this can be extended to a virtual tour of an indoor space for a group of users without a tour guide as well. The goal of this virtual tour would be to explore specific objects and exhibits that could have a similar theme that a user is interested it and learn about them while also remembering what they have seen and where they saw it.

4.1.2 Exploration Steps

A tour of the VE would take place by ensuring that users go to specified locations of interest or nodes. Since these could be quite far from each other there should be way points

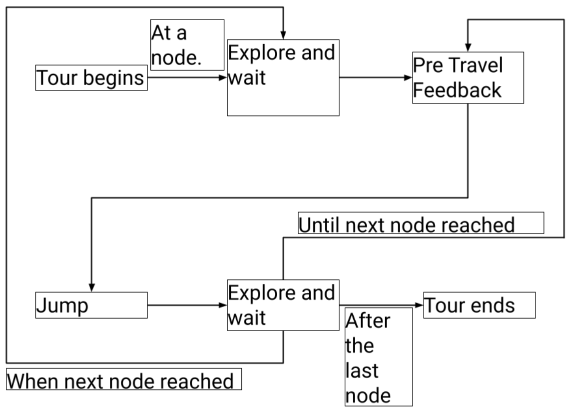

Figure 4.1: Steps that would be followed in an exploration of a VE using the automated guided jumping navigation technique.

in between each node so that users would travel shorter distances to the nodes, hence, justifying the navigation being a jumping metaphor instead of teleportation. As shown in Figure 4.1, when a user is touring the environment they start at the first node. Here they can explore and wait for a while till they are willing to move on. When they are ready to jump they get some form of travel feedback so they are aware that a jump is about to take place. Then a jump takes place to either the next node or a way point. The user can no explore and wait or again jump to the next node or way point. The jumps would keep taking place until the final node is reached and the tour ends.

Travel Feedback

Before a jump takes place, a user needs to know the following information:

- The location they will jump to.
- Their orientation after the jump.
- The time left until the jump takes place.
- Whether or not a jump is paused, giving them time to explore.

Pause to Explore

As the jumping is done automatically, it is important to provide the user with some way to control the technique. This can be done by allowing them to somehow pause the jumping either implicitly or explicitly so that they can take the time to explore or look around rather than being worried about automatically moving to the next position. Similarly, users would then also have the ability to implicitly or explicitly to resume once they are ready to continue. Resuming would reset the countdown to a jump so as to avoid sudden jumps after resuming. Looking away from the next node causes the guiding to be paused implicitly and looking back at it can cause the guiding to be resumed as looking around is a natural behavior that someone may use to explore an environment. For explicitly pausing and resuming some form of conscious user input to pause or resume the guiding is required instead.

Choice between Nodes

In addition to users having the option to pause, users should also have some control over the path they take. This can be provided by adding some nodes where a choice is given to the users between multiple possible nodes they can go to. Information and travel feedback about each node is given to the users and then they can select their preferred node from the given options.

4.2 Environment Setup

Once we came up with a suitable interaction design for the technique we had to decide how an environment would need to be set up to use this technique. Figure 4.2 shows a basic environment in which our guided jumping technique can be used. As mentioned in subsection 4.1.2, a user has to travel from one node to the next. As nodes are points of interest and can be far apart from each other, to ensure short jumps there are way points between them. The figure 4.2 shows these nodes as and way points as black and yellow spheres respectively. As we see in 4.1.2, sometimes there can be more than one node to choose from as the next node. This is indicated in the figure through numbers and arrows.

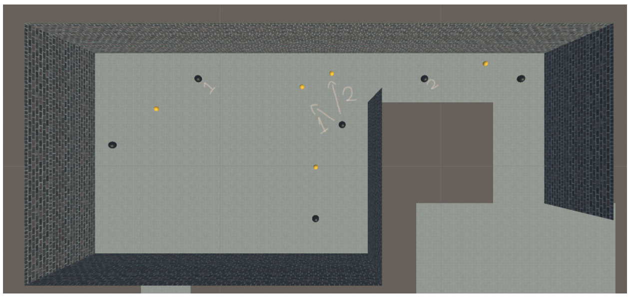

Figure 4.2: This is a potential setup of an environment in which the automated guided jumping navigation would be used. Black spheres = nodes, yellow spheres = way points, arrows and numbers where there is a choice between nodes

This environment setup with nodes, way points and choices is something that would be a part of the environment design by the creator of an experience or tour. The nodes have to be points of interest so should be placed where there is some exhibit or interesting object for users to look at. Nodes are numbered so that the next node can be linked to a node. Way points should also be setup between the nodes. Lastly, any nodes where there can be a choice between more than one next node is also set up accordingly.

4.3 Automated Jumping

Once an environment is setup with nodes and way points automated jumping can be carried out by moving a user from each way point or node to the next while keeping in mind important aspects of teleportation techniques as specified by Weissker et al. These are *'target specification, pre-travel information, transitions and post-travel feedback'* [1] and are what make the jumps comprehensible.

4.3.1 Comprehensibility of Jumps

The target specification in this case is automatic and has been preassigned as the next node or way point, except for when there is a choice between more than one way point or node as the next target. Pre-travel information is provided as avatars positioned at the target's location and facing the direction that a user would be oriented towards after a jump. In addition, the time left till the jump will take place is also indicated by a line that

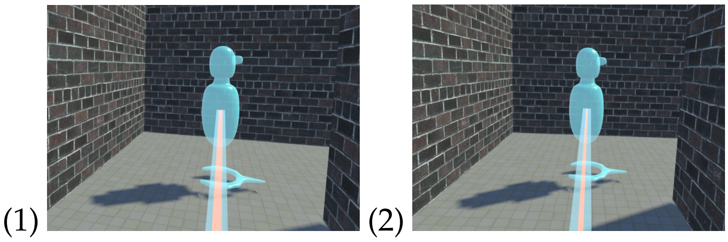

Figure 4.3: Avatar at target position facing orientation the user will face after jump. The orange line can be seen to decrease in width between (1) and (2) indicating time left till jump.

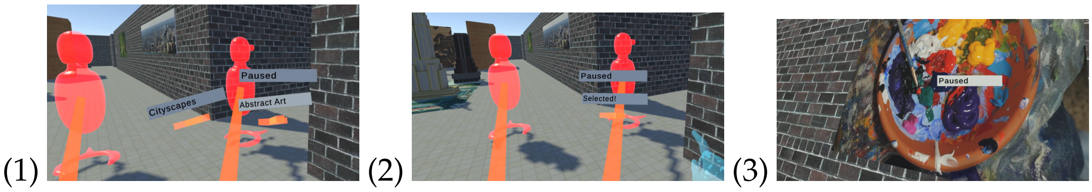

Figure 4.4: Feedback when making a choice or pausing: (1) Arrows and signs pointing to the different avatars indicating a choice. (2) The selected avatar is indicated by a sign while the arrow and sign for the avatar not selected disappear. (3) A sign showing that automated jumping has been paused.

gets narrower as less time is left. This can be seen in figure 4.3. We decided to go with simple instant transitions for the jumps. There is no specific post-travel feedback, however, after a jump users can already see the pre-travel information for the next jump and are therefore aware that they have completed the current jump.

Finally, there has to be feedback when the user has to make a choice or when they pause the automated jumping. This feedback is provided through User Interfaces (UI). To indicate a choice needs to be made by the user for what path they want to take, there is a combination of arrows and signs pointing to the avatars that indicate the next possible positions to choose from. On selection a sign that says *'Selected!'* is used to show which option has been selected. In addition, the arrow and sign for the option that is not selected disappear. Once feedback has been given for making a choice, the guiding continues with the node or way point represented by the selected avatar as the next node or way point. To indicate that the automatic guiding is paused, a sign that says *'Paused'* becomes visible. Figure 4.4 shows these different UIs for feedback on pausing or making a choice.

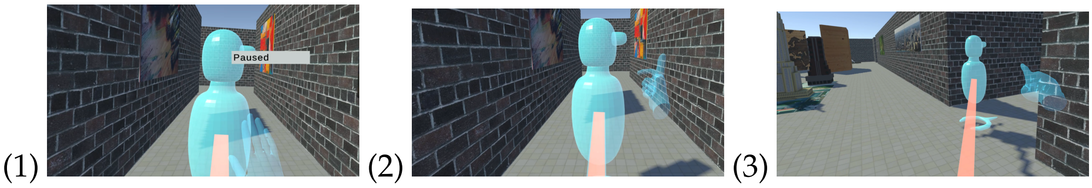

Figure 4.5: Gesture control to (1) pause, (2) resume and (3) make a choice.

4.3.2 Gesture Control

Since we wanted to reduce the learning difficulty for users and also the hardware that would be required to use the technique, we decided on allowing users to use hand gestures with a HMD that allows for gesture tracking. Users can pause and resume the automated guiding explicitly through hand gestures. They can also use a pointing hand gesture to choose the next node or way point when there is a choice between more than one. These hand gestures should be natural and represent how a person may do a similar action in a non-virtual environment. Figure 4.5 shows the hand gestures being used in our VE using an Oculus Quest.

5 Design and Procedure of the User Study

5.1 Hypotheses

In Chapter 4 we looked at a technique for automated guided navigation using the jumping metaphor and we also saw how the jumps in this technique could be made comprehensible so that the user would know when and where they will jump. The motivations and scenarios that might require such a technique were discussed in Chapter 3. Keeping in mind the motivation to have a virtual museum that novice VR users are able to explore we came up with the research questions $\mathbf{RQ_1}$, $\mathbf{RQ_2}$ and $\mathbf{RQ_3}$ that are mentioned in section 3.3.

To study the developed technique with regards to these research questions we decided to design a study that would compare our developed technique for automated guided jumping with a user controlled (free) jumping technique having visual guidance. With this study we hoped to prove the following hypotheses:

$\mathbf{H_1}$**:** Participants do not get more simulator sickness while using the automated guided jumping compared to free jumping with visual guidance.

$\mathbf{H_2}$**:** Visual previews before automated jumps will have similar comprehensibility of the jumps compared to free jumping with visual guidance.

$\mathbf{H_3}$**:** Automated guided jumping will reduce task load compared to free jumping with visual guidance.

$\mathbf{H_4}$**:** Users will be able to recall their path when using automated guided jumping as well as when free jumping with visual guidance.

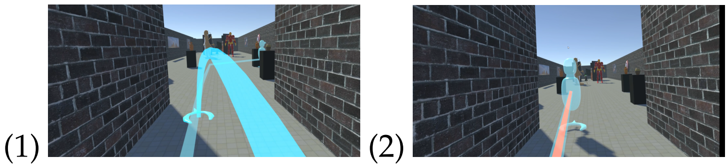

Figure 5.1: Free jumping with visual guidance.

Hypothesis $\mathbf{H_1}$ is important because we want to justify the need for automate the guided jumping without compromising on the reason for using jumping as the navigation metaphor, that is reduced motion sickness. To also justify that spatial awareness is similar in our technique versus free jumping the study must prove hypothesis $\mathbf{H_2}$ and $\mathbf{H_4}$. Hypothesis $\mathbf{H_2}$ also needs to be proved to show that the technique is easy to understand and users will not get confused when using it compared to free jumping. In order to prove the benefit of automated guided jumping over free jumping with visual guidance the study must show that $\mathbf{H_3}$ is true.

5.2 Study Task and Limitations

As the study will be comparing automated jumping with free jumping using visual guiding, it was important to plan a controlled study design such that there would be no other influencing variables besides the automation. Therefore, when developing the free jumping technique that would be used for comparison we had to make sure that the only difference between it and our automated jumping technique would be that the user would make the jumps themselves instead of being automatically moved. There are still nodes and way points in the scene that are used to show visual guidance with an avatar being visible at the next node and a path drawn through way points as in figure 5.1. The figure also shows the teleportation indicator with a curve pointing to it that users can use to select the position and orientation they want to be at after the jump.

As discussed in 3.2 one of the use cases for guiding techniques is virtual tours and we developed our technique for such a scenario as mentioned in section 4.1.1. Therefore, the study design also kept in mind a virtual tour situation and considered the potential problem situations that may occur and the possible tasks that may be expected when touring through a virtual space. For this study the task was narrowed to touring a virtual museum with exhibits and trying to remember the path taken as well as the objects seen. This is a useful task when going through a museum and gives answers about whether the techniques used are facilitating acquisition of relevant knowledge of the scene as we hoped to do so through our technique and can be seen in our research question $\mathbf{RQ_1}$.

This task situation for this study will not cover all possible situations that may arise when taking a virtual tour such as:

- Exhibits that are very close or far from each other.
- More than 2 possible paths to choose from at some nodes.

5.3 Variables and Conditions

Keeping in mind the task of touring a museum and remembering the path and objects, there are certain variables that need to be varied between the two techniques and others that need to be measured.

5.3.1 Independent Variables

As we saw in section 5.2, automation is the only variable that should be different between the two techniques that are being compared. This means that one technique will have automated jumping and the other will not but the visual guidance and ability to have a choice must remain the same. In addition it is important to keep the number of nodes and way points the same. It is also necessary to keep the environment and objects of similar complexity.

5.3.2 Dependent Variables

The variables that would depend on whether the technique is automated or not are related to the hypothesis that we introduced in section 5.1. The amount of simulator sickness needs to be measured somehow to answer hypothesis $\mathbf{H_1}$. A higher amount of simulator sickness is undesirable while lower amounts are better. Hypotheses $\mathbf{H_2}$ can only be answered by finding some way to determine comprehensibility of jumps. The more comprehensible users find a jump the better. The variable needed to answer hypothesis $\mathbf{H_3}$ is the task load that users feel they had. A lower task load means that users felt they had to make less effort to complete their task and is, therefore, better. Finally, we also need to measure path recall so that we can prove hypothesis $\mathbf{H_4}$. The more a user is able to recall their path the better. We will look into details on how these variables are extracted during the study in section 5.4.

5.3.3 Study Conditions

Since we have two techniques to be compared we decided to go with a within user design with 2 study conditions, one using the automated guiding and the other using free jumping with guidance. To avoid participants recall of the environment after the first condition effecting their recall of the environment for the second condition, it is necessary to have two different but comparable scenes. In addition, to avoid the environment or the study order impacting the results the techniques we decided to alternate the order of the conditions while keeping the environment order the same each time.

5.4 Study Procedure

In the previous section we defined variables and conditions for the study. Based on these we planned the study procedure which we will now outline in this section starting with the study setup followed by the study plan.

5.4.1 Study Setup

The study setup can be divided into three parts which we will discuss in this section. The hardware setup within a physical space, the virtual environment setup and the user feedback.

Hardware

As we implemented the technique using hand tracking for the Oculus Quest 2, the study was conducted using this HMD. The Quest 2 has Oculus Insight technology, which tracks changes in the users' position and orientation without need for external tracking. The play space was set to stationary so that users could remain seated while doing the task as there was no need for physical movement. However, to ensure participants could physically rotate, a revolving chair was setup for them to sit on rather than a stationary one. The participants were also equipped with the Oculus Quest 2 controllers but they only needed to make use of the right controller for the free jumping technique and did not need to use a controller for the automated jumping. The environment was displayed per eye at a resolution of 1832×1920 pixels and with a refresh rate of approximately 72 Hz. The headset was connected with a USB cable through Oculus Link, to a computer running the virtual environment on Unity. An additional laptop computer was also setup so that participants could answer question on it in between the tasks and at the end of the study. There was also some space on the desks with a paper for a drawing task for the path recall, which will be explained more in section 5.4.2 and is linked in Appendix A.1. Finally, the experimenter controlled study conditions via the keyboard connected to the workstation running the environment on Unity. Figure ref shows a drawing of the physical study environment and setup.

Virtual Environment

More than one virtual environment was used for the study. These could be divided into rooms between which the user would switch once each part of the study was conducted. There was one tutorial room in which tutorials for both techniques would take place. There were then two other rooms which were the actual environment for the study tasks. These rooms were a simple museum setup with three rooms connected by one T-shaped corridor and two simple corridors. The rooms had a number of exhibits with a total of 11. There were also 13 paintings distributed along the walls of the rooms and corridors. Top down views of these three rooms can be seen in figure 5.2.

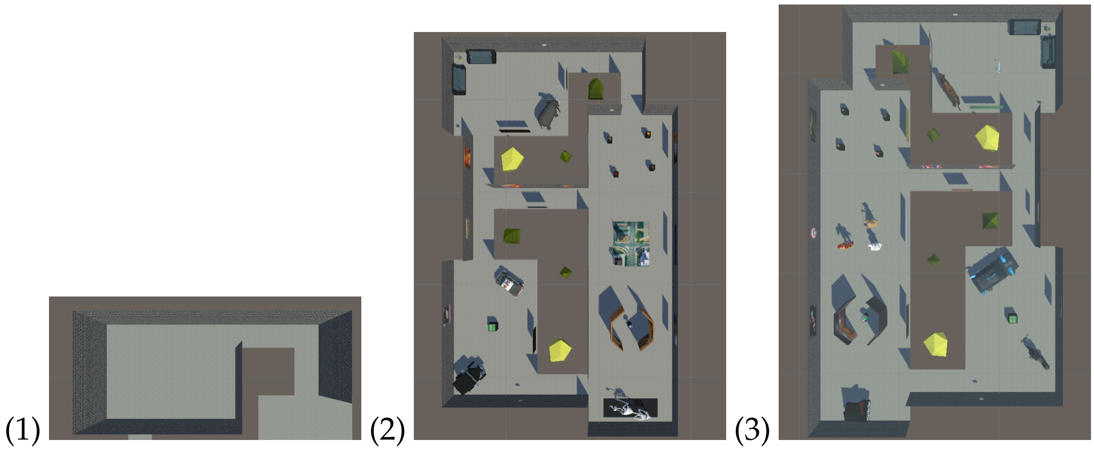

Figure 5.2: The virtual rooms used for the study with a (1) Tutorial room, (2) Room for Task A and (3) Room for Task B.

5.4.2 Study Plan

Questionnaire

While the study task in the virtual environment itself was very simple we required detailed feedback from users on certain aspects so that we could answer our hypotheses

5.5 Conclusion

6 Evaluation of the User Study

7 | Conclusion and Future Work

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A | Appendix

A.1 Questionnaire