Bauhaus-Universität Weimar
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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.

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Abstract

This is the abstract...

Contents

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 **??**.

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?

RQ₂: How can we maximize the comprehensibility of a sequence of automated jumps?

RQ₃: 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 3.3. This will be followed by details about development of the technique which can be divided into three parts; the setup of an environment and narrative structure for using this technique, development of automated jumping and finally how to make the jumps 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
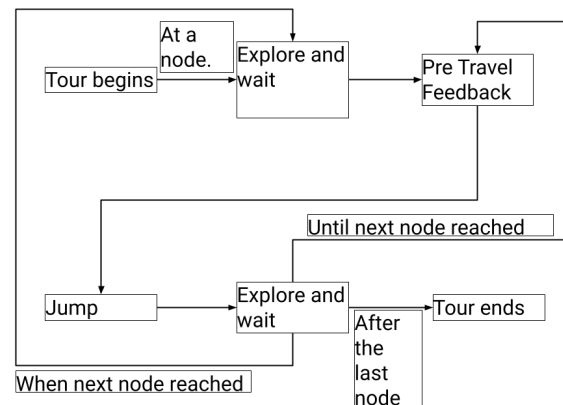
Figure 4.1: Steps that would be followed in an exploration of a VE using the automated guided jumping navigation technique.

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.

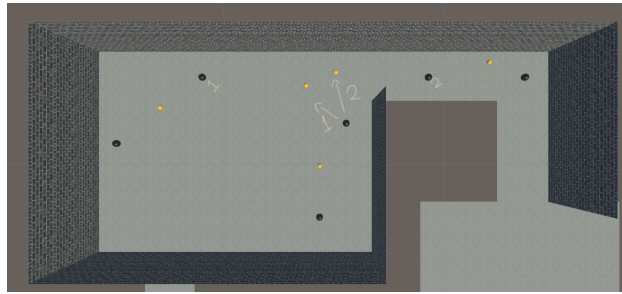- Whether or not a jump is paused, giving them time to explore.

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

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.

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

4.3 Automated Jumping

4.4 Comprehensibility of Jumps

5 | Design and Procedure of the User Study

5.1 Research Questions

In Chapter **??** 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 **??**. Keeping in mind the motivation to have a virtual museum that novice VR users are able to explore, we introduced the following research questions:

To study the developed technique with regards to these research questions we decided to design a study that would compare automated jumping with user controlled (free) jumping. It was important to have a controlled study designs such that there would be no other influencing variables besides the automation.

6 | Evaluation of the User Study

7 | Conclusion and Future Work

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A | Appendix

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