

Bauhaus-Universität Weimar
Faculty of Media
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Jumping for Guided Navigation in Immersive Virtual Environments

Master's Thesis

Ramsha Saad Thaniana
born on 07th October 1996 in Karachi, Pakistan

Matriculation number: 121766

First referee: Prof. Dr. Bernd Fröhlich
Second referee: Junior-Prof. Dr. Jan Ehlers

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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

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Contents

1	Introduction	1
2	Related Work	1
2.1	Navigation	1
2.1.1	Quality Factors	2
2.1.2	Travel Metaphors	2
2.2	Guiding for Navigation	3
2.3	Conclusion	4
3	Guided Jumping Motivation	1
3.1	Museum Tours	1
3.2	Storytelling	1
3.3	Conclusion	1
4	Automated Guided Jumping for Navigation	1
5	Design and Procedure of the User Study	1
5.1	Research Questions	1
6	Evaluation of the User Study	1
7	Conclusion and Future Work	1
A	Appendix	3

1 | Introduction

Many navigation techniques exist for both Desktop and Immersive Virtual Environments (VE) that define how users move 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-Dimensional (3-D) 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 they 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 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 this chapter we will look at use cases where navigation in a VE is required. These scenarios will be used to demonstrate the motivation for automated guided jumping for navigation which will be introduced in Chapter -.

3.1 Museum Tours

3.2 Storytelling

3.3 Conclusion

RQ₁: 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 for Navigation

5 | Design and Procedure of the User Study

5.1 Research Questions

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

RQ₄: How can guided navigation techniques facilitate the acquisition of relevant knowledge of the scene while avoiding motion sickness?

RQ₅: How can we maximize the comprehensibility of a sequence of automated jumps?

RQ₆: Will having guided jumping improve comfort and reduce task load compared to free jumping with visual guidance?

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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