

Navigation in Virtual Reality Space

Concepts of Navigation Methods

**IP5 Project of**

**Bär Dominic**

**Groux Marcel**

**FHNW**

**University of Applied Sciences**

**Degree Course: Computer Science / iCompetence**

**Supervising Lecturers: Arizona Stefan, Marcin Simon**

**Windisch, 20. January 2017**

Clarification of Honest

Hereby I declare to have written the present IP5 Project independently, without help of a third party and only under the usage of the declared sources.

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| --- | --- | --- |
| Brugg, 20 January 2017 |  | Brugg, 20 January 2017 |
| Place, date |  | Place, date |
|  |  |  |
| Signature Dominic Bär |  | Signature Marcel Groux |

Summary (Both)

Project Summary

Preface (Both)

Vorwort mit Danksagung

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1. Introduction (Dominic)

This chapter contains an overview of the project. It describes what has been accomplished with the project and which topics are covered.

## What has been achieved?

Within the scope of this project a prototype for methods of navigation in the virtual reality space has been created. This prototype contains five different methods of navigation covering the two main groups of navigation methods, teleporting and walking.

To further use this prototype in upcoming projects a concept containing suggestions for using the different navigation methods.

## Why has it been done?

The prototype was created to analyze the navigation methods in the virtual reality and to create suggestions on which navigation method to use in which environment and / or scenario.

## How has it been achieved?

The creation of the prototype can be divided into two parts. In the first part we research many different navigation methods and their used parameters. Based on those we choose a number of navigation methods we wanted to implement and created a concept and idea how we imagined them to be implemented. The second part covers the implementation and various self-tests on a weekly basis to create the prototype for the chosen navigation methods.

Regarding the technical aspects, we used the game engine UnrealEngine 4 and the virtual reality device HTC Vive.

## Readers Guide: How is the rest of the document constructed?

The document consists of two separate parts. The first one contains the theoretical aspects covering the problem and the research. The second part addresses the practical aspects of implementation and testing.

1. Initial Position (Dominic)

## Introduction

In this chapter the initial position of the project will be introduced. The Application domain will be described and an overall scenario will be shown. Furthermore, the project goals and scope will be stated.

## Application domain

**Anwendungsdomäne**

## Overall scenario

The project covers the research and analyzation of navigation method and the development of a prototype for navigation methods in the virtual reality. The overall goal is to create a concept of different navigation methods with suggestions for each method and their suitability in different scenarios.

### Target audience

The creation of the prototype is targeted for creators of virtual reality applications and / or games used in a home environment.

## Project Goals

The goal of this project is the generation of a concept about the navigation in the Virtual Reality space. The concept is based on a scientific research and should address the questions of the suitability for different navigation methods and the corresponding parameters (e.g. camera angle/area, scaling in space, …) within specific scenarios, which are to be determined.

Finally, the concept contains a thorough scientific analysis of VR navigation and its parameters, elaborated in a scientific approach and reflecting the current state of research of the Virtual Reality Community as far as possible.

The navigation methods, elaborated in the concept, should be implemented as a template for different scenarios and be tested thoroughly. Such that it can be shown which navigation methods are suited best for different scenarios. Thereby it is to bear in mind that the navigation that we are reviewing should be possible to use in a home-user-environment.

### Navigation Methods

The following navigation methods will be elaborated in the prototype:

* Walking in Place
* Walking by Leaning
* Scaled Walking
* Teleporting
* Jumping

Further details to each navigation method will be given in chapter 3.3 Research Navigation Methods.

## Project Scope

Project contains the following emphases:

* Research of navigation methods and their respective parameters
* Creation of a concept of how to implement the navigation methods
* Implementation of the chosen navigation methods
* Testing and analysis of the implemented navigation methods

## Limitations and Assumptions

### Limitations

We researched far more navigation methods than we have had to implement and test. Due to that we had to limit the number of navigation methods we implement in our prototype. We choose the navigation methods that are commonly used and those that interested us personally the most.

Furthermore, we had to cancel the dynamic walking navigation method stated in the project agreement due to not having the time to implement it aswell.

### Assumptions

Welche Annahmen mussten wir treffen?

1. Research (Dominic)

## Introduction

In this Chapter we discuss the problem of our project and show results of our research in the field of the application domain

## Problem

The community provides a variety of implementation and methods for the navigation in the Virtual Reality space. Many of those however couldn’t be tested and analyzed scientifically. Furthermore, the already existing scientifically elaborated concepts are not necessarily suited for the new VR Hardware and the User- Space available for the VR-setup, like the HTC Vive or the Oculus Rift, and the usage in a productive application with users that have varying know-how and experience in Virtual Reality.

## Researched Navigation Methods

As described in chapter “2.6 Limitations and Assumptions” we researched far more navigation methods than we could implement in the prototype. Therefore, the chapter is divided into two parts either covering the implemented methods or the various other researched navigation methods.

Each navigation methods contains the following properties:

|  |  |
| --- | --- |
| Description | Short description of the navigation method |
| Physical Translocation | Does the user need to walk in the physical space? |
| Physical Movement | Does the user need to do move his body in order to activate a navigation method. |
| Parameters | List of potentially needed parameters |
| Problems | List of potential problems concerning the implementation and usage of the method. |

### Implemented Navigation Methods

#### Walking in Place (WIP)

|  |  |
| --- | --- |
| Description | The user walks in place without changing his location in the room. |
| Physical Translocation | No, due to not moving in the room the physical location of the user does not change. |
| Physical Movement | Yes, the user needs to move his arms in a walking movement. |
| Parameters | * Speed * Acceleration * Deceleration * Camera Direction |
| Problems | * Wall Collision in the virtual reality * When does the character start to walk * Which inputs does the user have to give * Motion sickness of the user |

#### Walking by Leaning

|  |  |
| --- | --- |
| Description | The user leans towards the direction he wants to walk to. |
| Physical Translocation | No, due to not moving in the room the physical location of the user does not change. |
| Physical Movement | Yes, the user has to lean in order to trigger the virtual movement. |
| Parameters | * Location * Location (Head) * Speed * Acceleration * Deceleration * Camera Direction * Scaling |
| Problems | * Wall Collision * Detection of leaning degree * Scale-rate * Motion sickness |

#### Scaled Walking

|  |  |
| --- | --- |
| Description | The user walks inside the predefined space of the room. His physical translocation will be scaled up in the virtual reality space. |
| Physical Translocation | Yes, the user needs to walk in the room to activate the virtual movement |
| Physical Movement | Yes, the user has to lean in order to trigger the movement. |
| Parameters | * Location * Speed * Acceleration * Deceleration * Camera Direction * Scaling |
| Problems | * Wall Collision * Scale-rate * Motion sickness |

#### Pointed Teleportation

|  |  |
| --- | --- |
| Description | The user points towards a location he wants to teleport to. With clicking on a button he teleports to that location. |
| Physical Translocation | No, the user does not need to move around in the room. |
| Physical Movement | No, the only needed movement is to point towards a location and pressing a button. |
| Parameters | * Location * Camera direction * Speed of the teleport |
| Problems | * Camera direction after teleport (wall collision) * Camera transition |

#### Jumping

|  |  |
| --- | --- |
| Description | The user jumps in place. |
| Physical Translocation | No, the user does not need to change the location in the room in order to trigger the virtual movement. |
| Physical Movement | Yes, the user needs to jump in place in order to trigger the virtual movement |
| Parameters | * Location * Location (head) * Camera direction * Scaling |
| Problems | * Probably needs to be combined with other navigation methods * Physical exhaustion |

### Other Navigation Methods

#### Walking

|  |  |
| --- | --- |
| Description | The user walks inside a given space in the room. |
| Physical Translocation | Yes, the virtual location is based on the physical location in the room. |
| Physical Movement | Yes, the user needs to walk around in order to activate the virtual movement. |
| Parameters | * Location * Speed * Acceleration * Deceleration * Camera direction |
| Problems | * Wall collision |

#### Dynamic Walking

|  |  |
| --- | --- |
| Description | The user walks like in scaled Walking. The intention of the user is detected. |
| Physical Translocation | Yes, the virtual position is based on the user’s physical location. |
| Physical Movement | Yes, the user needs to walk in the physical room. |
| Parameters | * Location * Speed * Acceleration * Deceleration * Camera direction * Scaling |
| Problems | * Wall collision * Scale-rate * Motion sickness |

#### Auto Walking

|  |  |
| --- | --- |
| Description | The user looks down at his feet and starts to walk. |
| Physical Translocation | No, the user does not need to change his physical location |
| Physical Movement | No, the user needs only to look at his feet in order to trigger the virtual movement. |
| Parameters | * Speed * Acceleration * Deceleration * Scaling |
| Problems | * Wall collision * When does it start to walk? * When does it stop to walk? * Scale-rate * Motion sickness |

#### Walking by Button

|  |  |
| --- | --- |
| Description | The user presses a button on the controller to walk. |
| Physical Translocation | No, no physical change of the location by the user in the room needed. |
| Physical Movement | No, no physical movement besides pressing a button needed. |
| Parameters | * Speed * Acceleration * Deceleration * Scaling |
| Problems | * Wall collision * Scale-rate * Motion sickness |

#### Gaze-directed Teleport

|  |  |
| --- | --- |
| Description | The user looks towards a location he wants to teleport to. With pressing a button, he teleports to that location. |
| Physical Translocation | No, no physical movement required to activate the method. |
| Physical Movement | No, pressing a button is the only needed physical action by the user. |
| Parameters | * Location * Camera direction * Speed of teleport |
| Problems | * Camera direction after teleporting (wall collision) * Camera transition |

#### Room-to-Room-Teleportation

|  |  |
| --- | --- |
| Description | The user selects a room he wants to teleport to. By clicking a button, he teleports to the selected room. His location inside the room is dependent of the current location in the physical space. |
| Physical Translocation | No, the user does not need to walk in the physical space. |
| Physical Movement | No, no physical actions by the user needed. |
| Parameters | * Location * Camera direction * Speed of teleport |
| Problems | * Combining with other methods for walking in the rooms * Camera transition |

#### Zoomed Teleportation

|  |  |
| --- | --- |
| Description | The user looks into the direction he wants to teleport. With clicking a button he zooms in on that location. |
| Physical Translocation | No, the user is not required to walk in the physical space. |
| Physical Movement | No, no physical actions by the user needed. |
| Parameters | * Location * Camera direction * Speed of zooming |
| Problems | * Wall collision * Camera transition |

#### Climbing

|  |  |
| --- | --- |
| Description | The user climbs up a wall by using his hand to pull himself up. |
| Physical Translocation | No, the physical location of the user does not change. |
| Physical Movement | Yes, the user is required to move his hand as if he is climbing up a wall. |
| Parameters | * Location (head) * Camera direction * Scaling |
| Problems | * Probably needs to be combined with another method. |

#### Flying

|  |  |
| --- | --- |
| Description | The user flies by using his hand / controllers like wings to navigate horizontally and vertivally. |
| Physical Translocation | No, no translocation in the physical room required. |
| Physical Movement | Yes, the user uses his hand / arms like wings of a plane. |
| Parameters | * Location * Speed * Acceleration * Deceleration * Camera direction * Scaling |
| Problems | * Wall collision * Scale-rate * When does it start to fly? * Motion sickness |

#### Flying II

|  |  |
| --- | --- |
| Description | The user flies through the virtual world by pressing buttons |
| Physical Translocation | No, the user does not need to change the physical location. |
| Physical Movement | No, no physical movement besides pressing the buttons needed. |
| Parameters | * Speed * Acceleration * Deceleration * Scaling * Camera direction |
| Problems | * Wall collision * Motion sickness |

### Researched Parameters (MARCEL)

Add Description to each parameter

* Location (X- / Y- / Z-Axis) (Head-Gear)
* Location (X- / Y- / Z-Axis) (Hand-Controller)
* Camera Direction
* Camera Angle
* Speed
* Acceleration
* Deceleration
* Scaling

## Technical Research

The following subchapter will focus on the technical side of our research regarding the game engines and the virtual reality hardware.

### Game Engines

#### Unity 3D

Unity is a multi-plattorm game engine developed by Unity Technologies. It is commonly used for the development of video games for computers, consoles and mobile devices. Unity itself describes it as the world’s largest creative community and the number one game development platform[[1]](#footnote-1).

The included WYSIWYG editor makes it easy to get started and develop your first project. Another usefull resource for an easy start is the rapidly growing community, a variety of tutorials and a wide range of plugins and extensions freely obtainable or purchasable in the asset store.

As for the programming language, the commonly used language is C#, but other languages like JavaScript are supported as well.

Among the normal purchasable versions, Unity offers also a free-to-use version. However, when using the free version, they automatically include a predefined Unity splash screen prior to your game. If your created game or application reaches a certain amount of revenue you are forced to get one of the paid versions. There are no royalty payments.

#### UnrealEngine4

The UnrealEngine4 is a game engine created by epic games.

One of the outstanding advantages of unreal is the blueprint system, which allows you to combine blueprints of objects and properties with functional statements in a visual way.

As for the programming language, the commonly used languages C++ and UnrealScript (a java-based object-oriented script language).

Epic Games delivers no purchasable version of the UnrealEngine4. To compensate the free usage of the engine they ask for a 5% royalty payment after reaching $3000.- of revenue per product per quarter. However, there are some exceptions for certain types of projects. « Pay no royalty for film projects, contracting and consulting projects such as architecture, simulation and visualization. »

#### Comparison & Reason of Choice

Compared to Unity 3D the UnrealEngine4 loses in the amount of supported platforms. Unity supports a wide and still growing range of platforms, while Unreal only supports the big names.

The Unity 3D Asset Store and the UnrealEngine4 Marketplace have very little in common. The Asset Store focuses on plugins, extensions and assets, while the Marketplace strongly focuses on the distribution of asset content.

Another difference between the two engines is the blueprint system of the UnrealEngine4. With this system you can create the entire project without writing code by combining blueprints with functional statements.

Due to personal reason and a greater interest we chose to work with the UnrealEngine4.

### VR Headsets

#### HTC Vive

The Head Mounted Device (HMD) of the HTV Vive has a visual field range of 110° (diagonally), a resolution of 2160 x 1200 overall or 1080 x 1200 for each eye and an image refresh rate of 90 Hz. The 32 built-in sensors allow for a 360° movement tracking. With the front camera it is also possible to add physical objects into the virtual world.

The measurements of the position are taken by the two base stations mounted to the ceiling of the room. Each base station contains a sensor to track the position of the HMD. The position of the HMD is measured with a gyroscope and an accelerometer. The two base stations allow for a quadratic area with adjustable side length depending on the distance between the stations.

The user inputs are controlled by two hand controllers, one for each hand. The 24 sensors of the controllers allow for precise movement tracking. The multifunctional trackpad and the double-staged triggers with haptic HD-Feedback allow an entirely new virtual reality experience.

To connect the HTC Vive with a computer are two HDMI-, two USB-, and one audio slot needed. The audio slot is needed to connect headphones to the audio slot attached to the HMD.

#### Oculus Rift

Description of Oculus Rift

#### Comparison

Comparison

# Implementation (Marcel)

## Introduction (Dominic)

Praktische umsetzung, protyping process

Concept and ideas

## Walking in Place

### Concept & Idea

~~The concept of our walking in place navigation method contains the forward / backward hand movements of a person during jogging. This gives the user the feeling of movement without physically change the location in the room. But with that comes the problem of having the feeling of moving around without moving around. To change this, we wanted to find a way to add inputs based on the leg movement when literally walking in place. However, due to the lack of leg or feet sensors this is not possible yet.~~



Figure 1 - Walking in place concept draft

### Implementation

Description how it was actually implemented

Screenshot of blueprint (Different versions?)

Problems while implementing

### Parameters

Which parameters are relevant for this method

## Scaled Walking

### Concept & Idea

~~The idea of scaled walking is based on the limited physical space the user has to move, but the virtual space can be a multiple of that space. To be able to use the whole virtual space the physical movements are scaled up, so that the user can explore a multiple of the space of his physical space.~~



Figure 2 - Scaled walking concept draft

### Implementation

Description how it was actually implemented

Screenshot of blueprint (Different versions?)

Problems while implementing

### Parameters

Which parameters are relevant for this method

## Walking by Leaning

### Concept & Ideas

~~With walking by leaning the user leans towards a direction he wants to walk to. Once a certain threshold of the x-axis rotation is reached the virtual character begins to move into that direction. The problem with that idea is that it is more a head rotation than a full body leaning.~~



Figure 3 - Walking by leaning concept draft

### Implementation

Description how it was actually implemented

Screenshot of blueprint (Different versions?)

Problems while implementing

### Parameters

Which parameters are relevant for this method

## Jumping

### Concept & Idea

Description on how it was planned to be implemented



Figure 4 - Jumping concept draft

### Implementation

Description how it was actually implemented

Screenshot of blueprint (Different versions?)

Problems while implementing

### Parameters

Which parameters are relevant for this method

## Combining the navigation methods

Creation of prototype (combination of each method prototype, switch between NavMets)

# Testing (BOTH)

## Introduction (Dominic)

Introduction to the testing

## Test Numbers

14 tests

## Experience with Virtual Reality

In the first test we wanted to know whether the tested person has had experience with the virtual reality prior to the test. We expected the majority to have already had first contact with the virtual reality.

The results showed us that half of the test audience had had experience prior to our testing sequence.

## Ease of Learning

In this test we gave the participants time to get used to each of the four tested navigation methods. They had as much time at disposal as they needed to feel that they know how the navigation method works. We expected them to take one to two minutes to get the feeling for the method

### Teleport

Chartpair 1 - EoL Teleport

Results

### Jumping

Chartpair 2 - EoL Jumping

Results

### Walking in Place

Chartpair 3 - EoL Walking in Place

Results

### Walking by Leaning

Chartpair 4 - EoL Walking by Leaning

Results

## Pick & place

The test persons were asked to pick up a cube, start the timer and reach the other end of the room using the assigned navigation method. This test was done for each of the four navigation method once.

OBJECTS!!

We estimated the following measuerements

|  |  |  |
| --- | --- | --- |
| **Navigation Method** | **Time** | **Objects** |
| Teleport | 15 seconds | One object |
| Jumping | 20 seconds | One object |
| Walking in Place | 30 seconds | Two objects |
| Walking be Leaning | 30 seconds | Two objects |

### Teleport

Chartpair 5 - P&P Teleport Time

Results Time

Chartpair 6 - P&P Teleport Objects

Results Objects

* Exp saw more objects, only one has not noticed an object

### Jumping

Chartpair 7 - P&P Jumping Time

Results Time

Chartpair 8 - P&P Jumping Objects

Results Objects

### Walking in Place

Chartpair 9 - P&P Walking in Place Time

Results TIME

Chartpair 10 - P&P Walking in Place Objects

Results Objects

### Walking by Leaning

Chartpair 11 - P&P Walking by Leaning Time

Results TIME

Chartpair 12 - P&P Walking by Leaning Objects

Results Objects

## Jump’n’Run

Test description

We estimated the following measuerements

|  |  |  |  |
| --- | --- | --- | --- |
| **Navigation Method** | **Time** | **Accuracy** | **Presence** |
| Teleport | 15 seconds | 5 | 4 |
| Jumping | 60 seconds | 2 | 2-3 |

### Teleport

Chartpair 13 - JnR Teleport Time

Results Time

Chartpair 14 - JnR Teleport Accuracy

Results Accuracy

Chartpair 15 - JnR Teleport Presence

Results Presence

### Jumping

Chartpair 16 - JnR Jumping Time

Results Time

Chartpair 17 - JnR Jumping Accuracy

Results Accuracy

Chartpair 18 - JnR Jumping Presence

Results Presence

## Ease of Use

What tested, what expected

Chartpair 19 - EoU Navigation Methods

Results

## Problems during testing

* E.g. the ladder (or other objects) was always visible
* Button not easy usable
* etc

# Conclusion (BOTH)

## Introduction

Intro to conclusion

## Insights

Welche Erkenntnisse haben wir gemacht?

## Suggestions

Schlussfolgerung

Konzept Suggestions which NavMet where to use

Entwicklungsprozess

# Further Steps (Marcel)

## Introduction (Dominic)

This chapter discusses various topics that could have been implemented into the project. Those topics could be implemented in a further project.

## Marketplace UE4 / Unity3D

Create version for marketplace

## Graphical Navigation Menu / UI

Create menu for switsching navmet

## Composition of Navigation methods

Combine different navmet (e.g. Jumping and scaled walking)

# Reflection (Both)

## Introduction

In this chapter we reflect on our project work. We will talk about what we have learned / gained, what was good or bad and our time management. Furthermore, we will reflect on the collaboration within the team and with the coaches.

## Lessons Learned

### Dominic Bär

Lessons Learned Dominic

### Marcel Groux

Lessons Learned Marcel

## Time Management

Regarding the time management, we had difficulties to really estimate the needed time for the different tasks. Most of the difficulties with estimating the time for the project were based on the inexperience in the technologies. Especially hard was the calculate the time for the induction of the UnrealEngine4 and other virtual reality aspects since we did not know how effortful these tasks can get. Another difficulty was the at the beginning not defined navigation methods and the not yet clearly defined project goals. Those changed during the project when the prototype took its shape and everything was clearly defined in the project agreement. Furthermore, we had forgotten to include enough slack time in our management which lead to stress during the last few weeks of the semester.

For further projects we think the time management is one of the most important tasks for planning the project and the first step to success. Our own time management clearly needs to improve.

## Collaboration

### Team Internal Collaboration

Due to working together in the projects 1 & 2 we already knew how the other person was working and thus it was quite easy to get used to it again.

With the daily maintained Trello board we were able to get a structure in the project and an easy way to assign the various tasks to the better fitting person. In the end we ended up dividing the whole project into two parts, a theoretical and a practical to fit the personality and preferences of each of us.

### Collaboration with Coaches / Clients

The collaboration with Simon Marcin and Stefan Arisona was fine. Every week we had a meeting where we shortly discussed the progress of the project. They were motivated to give useful feedback and inputs to help us improve our work. The communication with them was very reliable.

# Index of Literature (Marcel)

L1. Internet

Add all used researched papers, stated with visiting date etc. (Savedate as visiting date)

Tutorials?

L2. Existing Projects

List of all existing projects we used

* Base project
* teleport

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[Chartpair 14 - JnR Teleport Accuracy 29](file:///C:\navVR\documents\technicalReport\technicalReport.docx#_Toc472628613)

[Chartpair 15 - JnR Teleport Presence 30](file:///C:\navVR\documents\technicalReport\technicalReport.docx#_Toc472628614)

[Chartpair 16 - JnR Jumping Time 30](file:///C:\navVR\documents\technicalReport\technicalReport.docx#_Toc472628615)

[Chartpair 17 - JnR Jumping Accuracy 31](file:///C:\navVR\documents\technicalReport\technicalReport.docx#_Toc472628616)

[Chartpair 18 - JnR Jumping Presence 31](file:///C:\navVR\documents\technicalReport\technicalReport.docx#_Toc472628617)

[Chartpair 19 - EoU Navigation Methods 32](file:///C:\navVR\documents\technicalReport\technicalReport.docx#_Toc472628618)

1. Attachment (Dominic)
   1. Project Agreement

Project Agreement?

* 1. Test Survey

Test Survey, with analysable results? -> Excel sheet

Google sheet evaluation

* 1. Attachment 3

1. https://unity3d.com [↑](#footnote-ref-1)