IFGI (WWU MÜNSTER, GERMANY) - UJI (CASTELLÓN, SPAIN)

Travel simulation inside an Immersive Video Environment (IVE)

Master Thesis Report

Erasmus Mundus Master of Science in Geospatial Technologies

Author:

Luis Bausá López

luis.bausa@uji.es

February 2013, Münster

Supervisor

Christian Kray
c.kray@uni-muenster.de
IFGI (Germany)

Co-Supervisors

Oscar Belmonte
belfern@uji.es
UJI (Spain)

Roberto Henriques
roberto@isegi.unl.pt
ISEGI (Portugal)

I. Abstract

This research study explores different methods and technologies to simulate travel inside an IVE that contains videos from several different locations. From the most adequate method and technology, a prototype is developed and evaluated. The videos are static, meaning that each video was recorded on a single location, and the orientation an coordinates doesn't change. We want to simulate the travel between two different locations. The video of a location is called a task, and the travels are called transitions. Using information gathered from previous studies and using the available technologies, this document will create a prototype of travel transition for our IVE. Finally, we are going to evaluate a tour composed of tasks and transitions on a group of test users to assess the quality and usability of the transition prototype. The prototyping and evaluation are based on the crucial quality and usability factors concerning our custom IVE system.

II. Keywords

Immersive Video Environment (IVE), Georeferenced Video, Virtual travel, Google Earth, Movement simulation, Virtual reality.

III. Preface

This document is the result of my master's thesis research project, which is the last part of the Master of Science degree in Geospatial Technologies. This research project is aimed at the prototyping and evaluation of travel transitions in the immersive video environment of the Sitcom Lab, located at the Institut für Geoinformatik (IFGI) of the Westfälische Wilhelms-Universität Münster (WWU).

The master program belongs to the Erasmus Mundus Master's program and three universities participate: WWU from Münster (Germany), UJI from Castellón (Spain) and ISEGI form Lisbon(Portugal).

Here I want to state that all the research and development work performed in this thesis document is original and has been done by myself. All the information sources used and work citations are included in the bibliography, and any possible omission is unintended.

A special mention to Google's interests is needed about the transitions: Even though it was stated several times in this document, and in the video files properties, that the transitions were created using Google Earth Pro (trial version), the final transitions doesn't include the GE logo. This is completely unintentional and a side effect of the resizing of the videos, as is explained later in this document.

I would like to thank Christian Kray, for being my supervisor and for all the help he provided.

Thanks also to all my student partners, it's been a pleasure so share this journey with them and to help each other.

A special thanks to my parents and family for making this possible.

And finally I want to dedicate this document to Esmeralda, the love of my life, for being always by my side.

IV. Table of contents

V. Table of figures

VI. Acronyms and terms used

- **API (Application Program Interface)**: It's a set of functions, procedures and/or methods that a certain library provides to be used by other software as an abstraction layer.
- **AR**: Augmented reality.
- **Boxplot**: It is a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation (sample maximum).
- **CAVE (Cave Automatic Virtual Environment)**: Usually a dome or a fulldome, showing a virtual environment with which the user can interact and move around.
- **DEM**: Digital Elevation Model
- **FPS (Frames per second)**: number of images or frames that a video file contains in each second.
- **GE**: Google Earth.
- **GSV**: Google Street View.
- **GUI (Graphical User Interface):** The interface allows the user to interact with the program, providing functionality. In our case, it allows the user to select, create, edit and delete the locations and it's information (coordinates, description, video file...).
- **HMD (Head-Mounted Display)**: It is a display device worn on the head with a small optical display in front of one or both eyes, called monocular and binocular HMD respectively. HMD also stands for Helmet-mounted display when mounted as part of a helmet.
- **IVE (Immersive Video Environment)**: In our case, it is a set of screens showing looping videos recorded at specific locations, with one purpose: to make the user feel like he/she is actually at that specific location. IVE can also stand for Immersive Virtual Environment
- **LOD**: Level of detail.
- **Prototype of transition**: It's a rudimentary implementation of a way to show the user what lies between the existing locations. It may also provide the user with some new functionality.
- **RW (Real walking)**: Travel technique simulating movement from the point of view of a person walking.
- **SBSOD (also SBSODS)**: Santa Barbara sense of direction scale, intended as a tool to self-report the spatial ability of users.
- **SSQ**: Simulator sickness questionnaire.

- **State or Location**: It is one of the points for which there is a long static video recorded, simulating the environment in a specific location, also called place or Placemark. Along with the georeference and the video, it can also contain some other information.
- **Transition**: Is the change between two locations or states, also called travel transition or travel simulation. It provides the user with information about what lies between the locations.
- **UI**: User Interface
- **VE**: Virtual Environment
- **VR**: Virtual reality.
- **VRUSE**: Virtual Reality Systems Usability diagnostic tool
- **VT (Virtual travel)**: Travel technique simulating non-walking travel, like flying, sliding, zooming... The speed can be constant or SISO, slow, medium, fast...

1.Introduction

Nowadays, the use of virtual reality and augmented reality systems is growing at a very fast rate, as very different fields find multiple uses for it. During its evolution, the virtual reality technologies have subdivided in many branches. The branch we are going to focus on are the immersive environments, which are artificial and interactive simulations of a world, real or imaginary, in which a user feels immersed, meaning that he gets a "feeling" of really being there, and he can interact with it.

In this document we are going to focus on simulating travel inside an IVE, which is a specific kind of immersive environment focused on playing videos of the real world at certain locations. When we go from one location to another, our IVE just changes the video file. We are going to simulate the travel between the current location and the destination.

1.1. Related work

There is extensive work related to virtual environments and their applications to many different fields. To better understand it, we will start by introducing the diverse types of virtual environments, finally focusing on the immersive environments. After we will focus on the design and evaluation methodologies upon which we have based our study, or have guided it through the right way.

1.1.1. Virtual Environments (VE)

The broad definition of Virtual Environment is a hard one to come by. Depending on which expert is asked, we can get very different answers. There is no general consensus on the specific characteristics that define all the virtual environments, and sometimes people can even call "virtual environment" to something that is not actually a virtual environment. But why is this? Our guess is that virtual environments have grown out of their initial definition, mostly due to the fast growth of this technology, caused by the exponential increase in computing power, and the multiple fields it has been applied to. And even though this boost was foreseen by many experts [A26, O11], there was nothing we could do to keep an up-to-date definition of these systems. To support and standardize these technologies, many non-profit organization like ImTech [O02] have born.

Many authors associate the term "Virtual Environment" and "Virtual Reality" as being the same thing, while VR is just a kind of VE. There are also differences of opinion whether the definition of VR entails that users must be able to interact among themselves, but that would leave out single-user systems. This leads us to one way of classification: single- and multi-user VEs.

To deal with this "inaccuracy" issue, some authors chose to focus on key differences between the different types of virtual environments. One of them is R. Schroeder in [A25], where he explains the differences between virtual environments and virtual worlds. But there is a common line to most definitions: a focus on the sensorial experience provided to the user.

It is much simpler to classify them by their purposes and capabilities. In this case, the two main groups would be Desktop VR and Immersive VR. Other important types are shared spaces, mixed reality and augmented reality environments. Some of these VE subgroups do entail being multiuser and providing interaction capabilities between the users, such as the collaborative environments. But one thing is for sure: the definition for each of these kinds of VE always overlaps at some point(s) with the others'. This means that, if you pick up one specific VE system, it will be possible to classify it in several of these groups. As an example a MMORPG, like the famous World of Warcraft, can be classified as a Desktop Virtual Environment, but also as a Virtual World and as a shared space.

1.1.1.1. Immersive environments (IE)

To some extent, all the VE must provide a sense of immersion, usually meaning "engaging" the user into the VE, but to be able to call it "immersive" it has to go beyond engaging the user: it must fool his senses into really "believing" or "feeling" he is there. Here we have again two different groups: the immersive and the fully immersive environments. The difference between them is that the fully immersive environments are designed to provide responses to the 5 senses (sight, sound, touch, taste and smell) using different technologies to achieve that effect. As it is very hard and expensive to do that, and sometimes completely unnecessary, in most cases only sight and sound, and sometimes touch, are simulated and they are called immersive environments.

Immersive (or fully immersive) environments are formally called immersive virtual environments, or IVE. The most common kind of IE are the head-mounted displays (HDM), but not the only one. Another type of IE are the CAVE systems, consisting in a dome where the simulation is projected. Finally, the immersive video environment (IVE from now on will stand for Immersive Video Environment, IE to refer to the generic Immersive virtual Environments) are a special type of IE where the simulation of the world is carried out using panoramic videos recorded from the real world. The panoramic videos can be obtained using specialized equipment or joining videos obtained from several cameras with different angles, as is our case. The reason to use panoramic videos is to increase the field of view. [A28] describes in detail the process followed to generate these videos and applies it to a wide variety of situations, like a football game, a rock concert and an outdoor mall.

A variation of these kind of environments are the Video-based Immersive environments, consisting on IE where the virtual world is rendered from videos taken from the real world to achieve a higher degree of realism [A27].

As a curiosity, Sharp developed a fully immersive video environment for the Huis Ten Bosch thematic park in Nagasaki, Japan, back in April 2011 [O12]. It was intended as a public attraction, called *5D Miracle Tour*, composed of 156 LCD panels of 60 inches each.

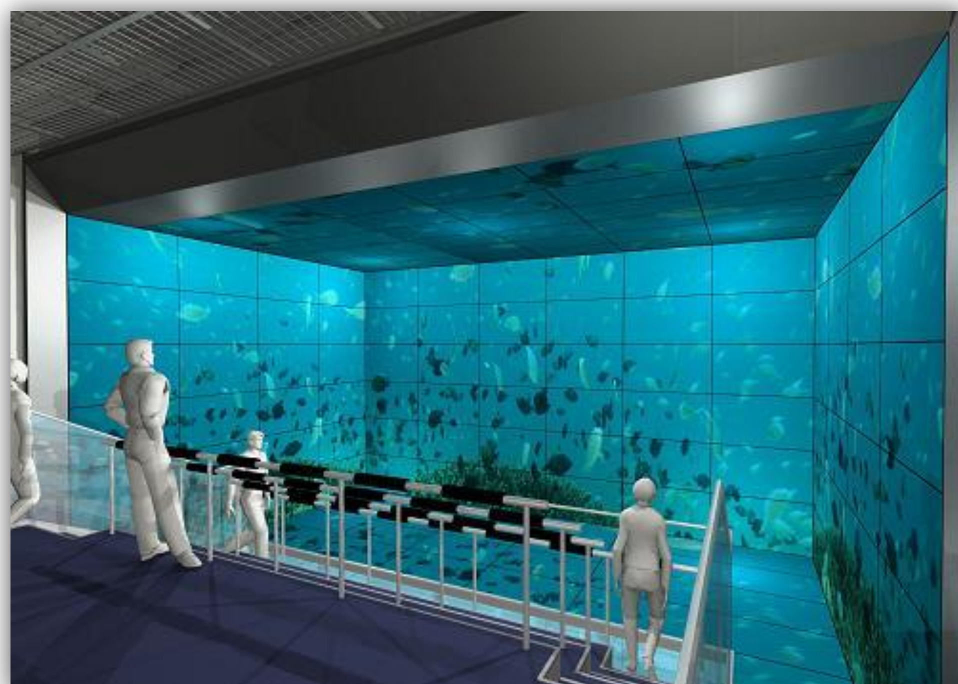


Image 1 - Sharp Fully Immersive Video Environment

1.1.1.2. *Uses and benefits of VE in the real world*

The VR systems, and specifically the Immersive Environments, have been applied to many different fields. One of the initial uses of IE is training: it provides the chance to prepare the subjects before the real situations, providing a safe environment and, in many cases, great money savings in resources, personnel and equipment. The US government has developed a pioneer program for soldier training using HMD (Image 2 left) [O14], but it has been a long time since IE are being used to train pilots, drivers and even miners [O01]. There is a whole business sector dedicated to these simulators.

Image 2 - US Soldiers VR training (left). Doctors using IVE for data visualization (right)

Another field where IE are causing a revolution is the medicine and health care [A18], where these systems are being applied for robot-assisted surgery, medical data visualization [O15], medical training [O14] and rehabilitation.

A third major field to which IE are being applied is the education sector, where platforms are being developed to monitor and stimulate [A30] learning, and enable interaction and collaboration among the users.

Of course, we cannot forget about the entertainment industry, which is making use of this technological revolution to embed IVE systems into gaming consoles [O03] and entertainment setups [O12].

A minor field of application of the immersive environments is performing user-based field studies through the use of IVE systems to simulate the field environment instead of performing the studies directly on the field. This small, but growing, field it the one our IVE system is applied to.

1.1.2. Design and evaluation methodologies for VE

One of the most prolific authors researching the design, evaluation and interaction techniques for immersive virtual environments is Doug A. Bowman. A great part of this thesis report is based and/or guided by his work starting by [A10], where he provides an evaluation of the different motion techniques used to travel inside IE and introduces the taxonomy of these travel techniques, and the quality factors upon which the travel techniques are compared. While [A31] is centered solely on the taxonomy and QF introduced earlier, [A01] is more focused on defining the methodology to evaluate the different travel techniques. [A04] is a testbed evaluation of the common use interaction techniques, where the taxonomy of the interaction techniques is introduced, and formalized later at [A03] along with their design and evaluation methods. Most of the content published in these papers is thoroughly extended and explained at his doctoral dissertation [A32]. In [A02] he provides a detailed report of things to take into account when evaluating the VE system usability. Finally, [A29] is a very helpful and detailed investigation on the effects of the different travel techniques focused on the spatial orientation of the users, while [A30] is focused on the benefits that information-rich VE can provide to stimulate learning and comprehension through the use of symbolic and experimental information.

Evan A. Suma [A11] provides a different evaluation of the different travel techniques, focusing on the cognitive effects of real walking and virtual travel. Part of the evaluation process involves the SSQ, introduced by Robert Kennedy in 1993 [A13] and complemented with metrics in 1997 [A15]. A research summary of the SSQ was published in 2007 [A14]. In 2004, a revised and extended version of the SSQ was created: the RSSQ [A17], but though we revised it, finally we did not use it. Some other publications to extend our knowledge about the relations between virtual environments, speed and simulator sickness [A07, A08, A16, A34, A37, A39], but there is not much to say here about them.

About the user studies, [A35] and [A36] provided an overview from different focuses about the methods and good practices to follow when conducting user-based studies on VE, such as different methods to analyze and evaluate the results and the meaning of them.

On the usability side, one of the first articles considered consists on a comparison of the methods available for usability testing [A05], and the information it provided was extended by [A33, A35, A36, A38], leading us to finally settle on the VRUSE questionnaire [A09] and modify it to test the quality factors identified in our specific case, first introduced by Bowman in [A10].

Other evaluation methods considered for our testing were the Santa Barbara Sense Of Direction scale [A21], designed as a spatial ability self-reporting tool, the NASA-TLX [A22], which measures task-load effort, VEPAB [A06], a battery of tests designed to measure usability of VR systems, and VET [A24] designed to measure the user experience of VE.

1.1.3. Other related work

Aside from the mentioned sources, some similar studies were revised and used to help us design our experimental setup. The first of them is a study of the application of VE to a vase museum [O16]. The second one is a study of the behavior of users inside a VE designed as a digital library [A40].

1.2. Motivation

The use of immersive environments for user-based tests is a very useful alternative answer to the eternal question: Should I run my tests on the lab or on the field? In many cases it is possible to do better.

The field tests are closer to reality, but it might be very difficult to avoid the influence of outside factors. Besides, in most cases it is a more expensive choice than lab testing.

The laboratory tests are almost always the cheapest and fastest choice, there is a higher control of the conditions, and the influence of outside factors can be avoided. Still, conducting test in labs has the drawback that it's still a laboratory, and not the real world, and some important factors may be impossible or too difficult/expensive to reproduce them in the lab.

The usage of immersive environments for user testing allows the researcher to control the environmental conditions and recreate the real world. This way it is possible to get the best out of both choices: field and lab testing.

Our IVE was originally created with that specific aim: testing real world situations inside the lab. It was created by the Sitcom Lab at IFGI. Here (http://sitcom.uni-muenster.de/research) it is possible to find information about some of the research projects carried out there.

My motivation is to **contribute to the development of this custom IVE by simulating travel movement** between locations.

1.3. Objectives

To successfully achieve our goal of simulating the travels between locations inside our custom IVE, we have several objectives to complete.

The first of them is to describe different methods to simulate the travel, and the available technologies that can be used for each method.

Secondly, we have to specify the desired characteristics that our travel transitions should have and choose the method and technology that fits them better.

Third, we need to determine a way to assess the usefulness of our travel transitions. We will search for different evaluation methods and select the one that fits better our needs. In the case that one is not sufficient, we will use a combination of them.

Finally, we will create a prototype of travel transition and evaluate it. From the results obtained in the evaluation process we will try to identify flaws and failures that should be changed to enhance the travel simulations.

2. Experimental Setup

In this section we are going to describe the kind of problem we are facing. To do so, we have to analyze our IVE, research for available technologies that could be used for our purpose and find the adequate evaluation methods to assess the usefulness of the travel movement simulation.

Once we have our problem fully defined, decided which technology we are going to use and selected the most adequate evaluation method, we will establish the steps we have to follow to build a prototype of the travel and to evaluate it.

2.1. Problem description

In this section we will start by introducing the IVE system we are going to work with. After it we will see the different types of travel transitions we can create and the technologies available that we can use to implement them and the various evaluation methods that we can use to test our implementation. Finally the last two subsections are dedicated to analyze the travel prototype that we want to build and to decide the technology and evaluation methodology that suits our needs better.

2.1.1. Our IVE

The IVE we are going to work with consists in 3 projector screens making a semicircle in front of the user's position. Three projectors are focused on the three screens, controlled by a desktop computer that works also as a server, containing the videos, the video player, and the GUI. The video player we are using is VLC [T01], controlled by a Java [T02] program. The GUI is web-based, so it can be remotely accessed from external computers using a browser. This GUI has been built using Grails [T03], and provides the user with some functionality to control the place the user wants to go to, automatically controlling and accessing the database containing the information about the different states existing in the system. There is also a web server that is accessed by an android [T04] app to display the coordinates of the location currently reproducing, but we are not going to need or use it for our experiment, so from now on we will omit any information about it.

The architecture of the system is notably fragmented, and in the diagram we only show the part of the system we are interested in. Each part of it has been built at different moments, by several different persons, without generating any documentation and using very different technologies for each part.

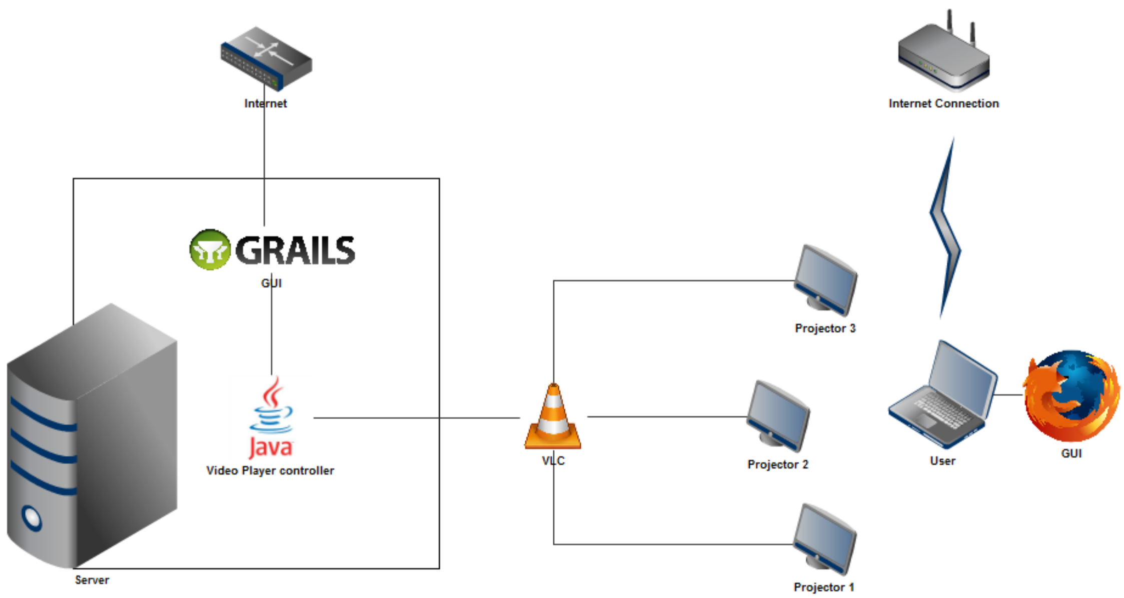


Figure 1 - Diagram of the IVE architecture

This custom IVE (Image 3) was designed with the purpose of conducting user studies as an alternative to the field providing a hybrid solution between field and lab, but it's functionality and uses have been extended when needed to match the requirements of the different investigations that have made use of it. More information about the Sitcom Lab and some of the investigations conducted using this IVE can be found at [O04].

2.1.2.Technologies considered

Several different technologies have been considered and exhaustively investigated to find their capabilities and limitations, both at their current status and the future expectations of each. Those technologies have been classified depending on the kind of travel transition that can be created by using them. At Table 1 we can see the different kinds of travel transition that have been considered for our specific environment, along with a representation of the technologies that can be used to bring them alive and the pros and cons of each transition type.

The technologies chosen are not the only ones that can be used, in most cases these are plenty of similar technologies available, but the most representative. Also, only technologies with global coverage have been selected, and the technologies with limitations to one or just a few countries have been discarded completely. Finally, we have given top priority to the free and/or open technologies to minimize costs.

Table 1 - Types of travel transitions

	Description	Technology	Benefits	Drawbacks
Map	Displaying a map showing both the origin and destination of the travel and some contextual information	Google Maps, Open Street Maps, Bing Maps, Yahoo Maps	Simple and easy to implement. Can be automatically generated. Can be created on the go or previously stored.	Non realistic. Only an abstraction of the world is shown (map). Reduces presence
Image slideshow	Display a slideshow of images of the path between the origin and the destination.	Panoramio, Flickr, Google Street View	Relatively simple to implement. A temporal frame for the images can be selected (day/night, winter...)	Images might not be available. Path selected might not be the user's choice. Time frames, resolution, luminosity... usually differ between images
Real video	Display a video, or pieces of video, of the path between origin and destination	3-Camera system mounted to record the original videos of the locations	Most realistic. If created specifically for this purpose we can control quality and consistency.	Most expensive solution. Long travels take very long. Video files really huge.
Virtual travel	Virtual simulation of the travel between origin and destination. Different travel techniques can be used, like RW or flying.	Google Earth, Google Street View	Multiple travel techniques can be simulated at speeds of our choice. Information LOD easily adjusted. High realism capabilities.	Automatic creation highly complex (yet). GE: places with few or nonexistent 3D buildings produce worse results. Resolution limited by the technology.

For the **Map** transition type, the most important technology is Google Maps. If we are looking for an open license, then OSM is the best representative.

- Google Maps: The GM API [T05] provides a wild amount of functionality. It is possible to choose among different types of basemaps, zoom and orientation can be easily adjusted, same as the LOD of the displayed information, and the KML language can be used to import/export data from it. Among all the web map services available, it provides the vastest amount of functionality, language support, embedding options and geo-data available. Another advantage is the enormous community of users and developers behind it. Its services are managed under a proprietary license.

- OpenStreetMaps: it runs under an open license, and all the information it provides has been created by volunteers. Several kinds of basemaps are available. The functionality provided by the API [T06] is limited compared to GM, and for some places the information is obsolete or nonexistent. Also, satellite imagery is not available from OSM.

- Bing Maps [T14] and Yahoo Maps [T15] run also under a proprietary license. The functionality provided by their respective APIs is mostly if not completely covered by GM. Also, Yahoo Maps is about to be shut down soon after making partnership with Nokia.

For the **Image Slideshow** transition type, GSV provides a different approach than Panoramio or Flickr.

- Google Street View contains a database of high quality georeferenced images that can be retrieved through its API [T07]. This images are obtained using specialized hardware with the purpose of picturing every street of every city. There are many emerging technologies similar to GSV, i.e. earthmine [O05], MapJack [O06], CycloMedia [O07], driveme.in [O08] and Bing Maps [T14]. Some of them provide an even better quality service than GSV, but most of them have severe coverage limitations (from just one city to a few countries), their services are paid-for, or no API is offered at all. GSV also has limitations and some streets are not covered, but still its coverage is far ahead of the rest.

- Panoramio [T08] and Flickr [T09] are oriented as platforms where anyone can upload their georeferenced photographs freely. It is also possible to display those pictures in a map. The main drawback of both of them is that those pictures, being freely uploaded by users, have different qualities, people are usually the main object, the georeferences can be inaccurate, no orientation is provided, and there many places without any picture.

The **Real Video** transition type has the potential to produce the best results, or at least the best image quality, for our specific problem, but at the expenses of very high costs and amount of resources. A great amount of hours and work would be needed to record and process the videos of every path we want to simulate, using very expensive specialized equipment and software. Also, the size of the video files is something to take into account, with an average size of 3 gigabytes per minute of processed footage. A very interesting Swiss technology, most appropriate for our purposes, was considered as an alternative, VideoStreetView [O09], but its coverage was very limited and it is no longer online, only to be found at the Internet Archives [O10].

The **Virtual Travel** transition type is a simulation of the travel in a virtual environment. For our case, the virtual environment is a representation of the real world.

- Google Street View: as the API in its current state can only provide static imagery, one way to skip over this limitation is to perform the travels manually and use a desktop recording tool to save them as video files. Of course, this raises a whole new set of problems and limitations: the video output is limited to the display resolution, each travel must be recorded separately, it takes time to load and render the online data, routes for each travel must be planned in advance... And, as each new travel must be planned and manually recorded, this method implies spending a vast amount of time to generate them. Also, long-distance travels can take a lot of time or be utterly unfeasible.

- Google Earth: this tool is a virtual representation of the Earth generated from aerial imagery and DEM, and enriched with many layers containing a lot of geo-referenced information like place names, borders, roads, 3D buildings... The user can explore this model from any point of view and easily add elements of his own, like PlaceMarks, routes and tours, and adjust the view by selecting distance, orientation, angle and, in the case of the routes and tours, the speed. To simulate the travels, we can choose between two different methods: routes and tours. By using routes we will follow a path at a constant speed from a view of our choice. In the case of the tours, we will "fly" between locations at a SISO speed adjusted indirectly: we establish the time it should take to go from one location to another, and GE adapts the speed internally. The API in its current state doesn't provide an easy way to create those tours (we would have to create the camera movement by ourselves), and no way to save them as video files, but the Pro and Enterprise versions have a Movie Maker plug-in to save tours as video files.

- Other: There are some other tools similar to GE, like OssimPlanet [T16] and NASA World Wind [T17], but none of them provide as much functionality (useful to us) as its rival.

Finally, we can enhance our prototype by using a combination of the presented technologies and/or adding textual information, maps, images, sounds, video effects (fades, overlays...), etc.

2.1.3. Evaluation methods

From the wide variety of existing evaluation methodologies available, none was found that was specifically intended for immersive video environments and that could be applied to our case. Nonetheless, we could find some evaluation methods intended for virtual environments or for general/diverse purposes that we could directly use or adapt to suit our needs. A brief definition of the most important methods considered is provided next:

- **NASA-TLX** (Task Load indeX): Developed in 1988 by Sandra Hart [A22], *NASA-TLX is a subjective workload assessment tool [that] allows users to perform subjective workload assessments on operator(s) working with various human-machine systems.* [It] *is a multi-dimensional rating procedure that derives an overall workload score based on a weighted average of ratings on six subscales* [...] *Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort and Frustration. It can be used to assess workload in various human-machine environments such as* [...] *simulations and laboratory tests* [T18]. Since its creation, it has been cited by over 550 studies [A23], and a recent search (Nov. 2012) at Google Scholar reports almost 8000 related articles.

- **SSQ** (Simulator Sickness Questionnaire): Developed by Kennedy et al. in 1993 [A13]. this method quantifies simulator sickness based on a list of 16 symptoms, rated using four levels of severity (none, slight, moderate, severe), divided in three subscales: nausea-, oculomotor- and disorientation-related symptoms. The total severity score is composed from these three subscales [A15]. *The SSQ is currently the gold standard for measuring* [Simulator Sickness] [A14].

- **RSSQ** (Revised Simulator Sickness Questionnaire): Developed in 2004 by Do Hoe Kim, Donald E. Parker and Min Young Park [A17], it is based on the SSQ to measure simulator sickness. The list of symptoms is extended to 24 and distributed in 4 factors. The new factor added is Strain/Confusion. Instead of the 4-point scale used in the SSQ, a new 11-points (0=none, 11=very severe) scale is used for scoring.

- **SBSODS** (Santa Barbara Sense Of Direction Scale): Developed in 2002 by Mary Hegarty, Anthony E. Richardson, Daniel R. Montello, Kristin Lovelace and Ilavanil Subbiah [A21]. It is a self-reporting method to quantify environmental spatial skills, commonly called sense of direction (SOD). The questionnaire consists of 15 questions, rated from 1 (strongly agree) to 7 (strongly disagree), about various environmental everyday tasks, like giving directions and estimating distances, and the sense of direction.

- **VRUSE** (Virtual Reality Usability assessment tool): Developed in 1999 by Roy S. Kalawsky, [it] *has been* [specifically] *designed to measure the usability of a VR system according to the attitude and perception of its users* [A09]. It identifies 10 key usability factors of VR environments. It can be used both as an evaluation and a diagnostic tool for virtual environments, and produces great results when used in conjunction with other evaluation methods. The questionnaire has 100 questions divided in 10 sections, one per usability factor, and it can be adapted to suit the needs of specific environments.

- **VET** (Virtual Experience Test): Developed in 2010 by Dustin B. Chertoff, Brian Goldiez and Joseph J. LaViola. [It] *is a survey instrument used to measure holistic virtual environment experiences based upon the five dimensions of experiential design: sensory, cognitive, affective, active, and relational. Experiential Design (ED) is a holistic approach to enhance presence in virtual environments that goes beyond existing presence theory (i.e. a focus on the sensory aspects of VE experiences) to include affective and cognitive factors* [A24].

- **VEPAB** (Virtual Environments Performance Assessment Battery): Developed in 1995 by Donald R. Lampton et al.. [It consists] *of an integrated battery of tasks to measure human performance in immersive virtual environments* [A06]. It is one of the first methods published to evaluate human performance in IVE's, and it was initially intended [...] *to determine those technologies that produce cost-effective transfer of training from VE practice to real-world performance, and practices for the effective use of these technologies* [A06].

2.1.4. Prototype analysis

According to Bowman [A10], the quality factors of travel in virtual environments are: **speed**, **spatial awareness**, **information gathering** and **presence**. All these four factors are closely related to each other. Knowing this, we are going to analyze the nature of our travelling technique to set the importance of each of the factors. In [A10] 7 different quality factors are stated, but we have ruled out accuracy, ease of learning and ease of use from our factor list because they are unimportant to us, as we travel directly to specific locations, we have a 100% accuracy, also there is nothing to learn or to use in our travel technique because the user has no control over it.

If we review the taxonomy [A01] of travel techniques for virtual environments, the target selection would be a discrete selection from a list, but made by the evaluator, not by the user; the velocity/acceleration can be either constant or automatic (SISO); and the input conditions are automatic start and stop. We have selected these options among those we could use to be able to rule the existing system out of the evaluation as much as possible.

About the speed, Bowman [A10] demonstrated that **jumping between locations produces disorientation**. Also in the same study, we realize that constant speeds reduce disorientation, and that slower speeds increase spatial awareness and presence, but with the drawback that they may take a too long time. It also points out that the reason for the bad marks obtained, in that same investigation, in the SISO (slow-in slow-out) speed may have been in the implementation.

In Figure 2 [A11] we can see a comparison of the virtual travel (VT) versus the real walking (RW) inside the virtual environment. If we apply this knowledge to our investigation, the navigation and collisions make no sense, because the user does not control the travel, just the destination. We can also assume that the RW is the equivalent of the low speed travel mentioned in [A10] and that the SISO travel is a version of VT. With this information, and taking another look at the mentioned table, we can see that both options are fine for our VE, but the slow speed (RW) has the drawback that it takes too long, so **the virtual travel is better suited to our needs**.

Goal of VE Application	Preferred Travel Technique
Supporting Memory	RW or VT
Supporting Cognition	RW or VT
Similarity to Real World	RW
Faster Navigation	RW
Reducing Collisions	RW
Reducing Simulator Sickness	VT

A summary of our conclusions based on the results across experiments comparing real walking (RW) to virtual travel (VT) in complex virtual environments.

Figure 2 - Evaluation of the cognitive effects of travel technique in complex real and virtual environments

In [A10] we can also observe that the way of measuring the spatial awareness is to measure the opposite: the disorientation. One way we can measure the disorientation is by measuring the simulator sickness, and the virtual travel is also better at reducing it.

To increase the spatial awareness we will have to provide the information about where the user is and where he/she is travelling to. This is closely related to the information gathering factor: we have to provide the user with some information in a way that he is able to quickly understand that information. The information that should be provided to the user is the location of the origin and the destination and the orientation of the view in each of them. Providing information about the surroundings of both places and what lies between them can also help enhance the spatial awareness.

As for the presence, that means providing a travelling effect as close as possible to the real world. It doesn't mean that the travel has to be simulated as a real travel, but that it should provide the user with the "feeling" [A10] that he/she is going from some place to another. This rules out completely jumping between locations and leaves us with the choice of following a path between those locations or flying from the current one to the destination. If we travel the path at a slow speed, we would be using an equivalent of real walking, while in any other case it would be a virtual travel.

The aim of our IVE is to make you "feel" you are in a certain location, so the travel cannot take long because the user might get bored while waiting to arrive from one place to another in long travels. This fact discards the RW or slow speeds. The fast speeds produce disorientation and reduce presence [A01], so we have only left the SISO speed or a medium constant speed. In the case of a medium constant speed we face again the drawback of time: a long distance travel may take a too long time. This means that, for our purpose, we will have to settle for the SISO speed, and choose a good implementation of it that doesn't disrupt the sense of immersion or reduce spatial awareness.

Image 3 - Snapshot of our IVE from the user perspective

Summarizing, the characteristics (functional requirements) identified for our travel transition prototype are the following:

- Speed: SISO (Slow-In Slow-Out).
- Presence: provide a very realistic simulation of the travel.
- Spatial awareness: provide the user with the location and orientation information.
- Information gathering: provide the sufficient information in a meaningful way and at the right time.

If we include the system requirements, we add a few characteristics:

- It must be an AVI video file
- Resolution: 5760x1080 pixels @ 25 fps

2.1.5.Technological choice

Taking into account the previous description of the travel transition we want to prototype, from the previous list of transition types we can only use three of them: the video of the path, the Google Street View path, and the Google Earth path or flight (of course they can be combined with the map or the textual information).

The video of the path is ruled out because we have not enough resources for it in the long run: we cannot (meaning it would be an unnecessary waste of resources) take all the videos of the paths between each 2 locations manually (the number of videos has exponential growth) and nowadays there is no framework of georeferenced videos that would allow us to retrieve volunteered georeferenced that can be useful to us.

As for the Google Street View solution, the main drawback is that the current API does not yet allow the user to automate the creation of the transitions or even to program them, so far you can only get pictures from it and make a slideshow out of them. Also, there are many places that the GSV cannot or have not reached.

In Google Earth [T10] we have a different problem, which is also a problem in the GSV solution: we cannot create the videos automatically, only manually. In the case of GSV it can only be done with a desktop recording tool, while in GE we can use the movie maker plug-in in the pro version or use the desktop recording tool. An advantage of the GE approach is that the effect of the camera when flying from one place to another is SISO, and apart from the fact that we can tweak it in the preferences, it has been used and tested by all the millions of users of GE with a general satisfaction.

As stated earlier, in GE we can choose either to follow a path between locations, or fly directly from one point to another. In both cases the user can see the compass (orientation) and the location of the origin and destination, along with their surroundings and what lies between them. Knowing all this, we are left with two options that would suite our needs: GE flight or GE path. As the aim of our IVE is to reproduce the videos recorded for the locations, we can assume that the user is not so much interested in following a path from the origin to the destination as he is on arriving to the targeted location, so **the best technological choice** in our case **is the GE flying**.

Also, in the options that involved a path we would be in a new dilemma: which path to choose? The shortest path? The fastest path? The path with most monuments? Walking, by car or by bus? To solve these issues, we would have to either make assumptions of the user needs, or provide the user with the functionality to choose for him/herself. And as GE and GSV current APIs cannot provide this functionality yet, the path choice is again ruled out. And this problem exists also in the option of the video of the path: we cannot take videos of every possible path, and we cannot yet use VGI to retrieve them.

As a conclusion of this, we have decided to **use the GE flying method to create the travel transitions**, both because other choices have been discarded and because it provides the most efficient and promising method to generate the adequate travel transitions for our IVE. This means using Google Earth Pro and its Movie Maker plug-in.

Using Google Earth Pro for our purposes has its benefits: it grants a very realistic simulation of the world, it has a Movie Maker plug-in to save tours to video files, the amount of information displayed can be controlled and adjusted to match our needs and we can control the speed of the travel. Another reason to choose GE is that it has millions of users of all kinds, and thus it is permanently growing, so it is important to consider that future revisions of the API may provide sufficient functionality to create a program to automatically generate the travel simulations instead of having to do it manually. But another great benefit that will be of great importance to us is that it has one of the most, if not the most, used and tested implementations of the SISO speed, making it ideal for our system. Finally, the way that GE handles the SISO speed is ideal for our purposes: we decide how much time should be spent to fly between places and GE automatically adjusts the speed, meaning that all travel transitions will have the same time length regardless of the distance covered in the travel.

It's also important to mention that the simulation of the travel must be really close to the real world, because they will take place between videos of the real world and a non-realistic simulation would completely disrupt the sense of immersion by distracting the user and focusing his attention in the differences between the real and the simulated scenes.

As for the evaluation methods, none of them suits all our needs by itself, so we are going to use a combination of them. We have decided to use the SSQ and part of the VRUSE questionnaire to test our travel prototype. The SSQ will evaluate the correctness of the speed chosen, while the VRUSE will evaluate the spatial awareness, the information gathering and the presence.

There are several reasons why we have chosen this methods among all the considered methods. In the case of the SSQ and its competitor, the RSSQ, we chose the SSQ over the newer method because the RSSQ added unnecessary complexity to our evaluation, but mostly because the SSQ has already been used in plenty of user studies, of a very wide variety, with published results that could be used as a reference to know what outcomes we should be expecting.

The reasons to select the VRUSE among the rest is that most of the remaining methods were mostly oriented to the UI (user interface) capabilities and the user behavior and responses when interacting with it. As we wanted to isolate the already existing system as much as possible from our evaluation and focus on the travel prototypes, we are not interested in testing the GUI. The only method remaining still capable of testing the rest of the quality factors identified was the VRUSE.

To evaluate our travels we are going to create a tour video containing a shortened version of some of the videos of the locations and, between them, a simulation of the travel from each location to the next one. A group of users will be selected and evaluated.

2.2. Prototype setup

To build our prototype we are going to need several software packages. The first and most important is the Google Earth Pro with its Movie Maker plug-in. This plug-in will let us save the tours of the transitions as video files. The output format is WMV 11 (Windows Media Video version 11). The maximum resolution we can use is 1920x1080px, so we will have to resize them to match the IVE videos. We can select a frame rate up to 50fps, but as the IVE videos are 25fps we will choose the same. We could choose a higher frame rate and downsample the videos later, but the result would be the same with the difference that it would take much longer to obtain the original video files from GE and to convert them to AVI. As we are not owners of a GE Pro license, we will order a free trial license that will work for 7 days, time enough to save the transitions to video files.

The second piece of software is a tool to resize and convert our videos to AVI format, called Any Video Converter 3.5.7 Free version. We have chosen this tool among many other video converters for several reasons: it is free and very simple to use, you can convert between almost any kind of video format, you can resize and trim video files and you can remove the audio track easily.

But the most important reason is that, among all the similar software, it was the only one that could handle the resolutions of our videos. In most of the similar tools, the output resolution is limited or can only be selected from a list of presets.

The last piece of software we will use is VirtualDub 1.9.11 [T12]. We will use this tool to paste together all the video files of the locations and the transitions into a single video file.

Apart from the software packages, we will also need the videos of the locations and their coordinates.

We have selected 9 places for our tour. That means creating 8 transitions to travel between the places, plus 2 extra transitions: the initial and final transitions. These two transitions differ from the rest in one key aspect: while all the regular transitions are related to two locations, these initial and final transitions are only related to one location. The initial transition will start with a view of the world, and zoom in until it arrives to the first place visited by our tour. The reason to include them is to introduce the user to that place's location, because if we started directly with the video of the first location, the user would not know where it is unless he already knew the place and recognized it, and the spatial awareness would be considerably reduced. The final transition is a similar but reversed version of the initial one: it starts at the last place visited and zooms out until we have a view of the world.

Now we will briefly explain the process of creating the transitions, but we can see a more detailed explanation in section 3.

To create the travel transitions we will first create, in GE, a placemark for each of the places we will visit and manually fix the orientation to match the videos' orientation. After that we will rename the transitions using the template NN - STREETNAME, where NN is a number corresponding to the order in which we will visit the places and STREETNAME is the name of the street(s) where the placemark is located. We will also change the icon of the location to the numbered icons , each one with the number corresponding to their order.

For each of the transitions we will create a folder, and inside it we will copy the PlaceMarks of the origin and destination of the travel. For each of these folders we will generate the tour of that folder and save it. Finally, using GE Pro, we will open the movie maker plug-in to save each tour as a WMV video file selecting the maximum resolution available and 25fps. Finally we will have to resize the videos to 5760x1080 pixels to match the IVE videos.

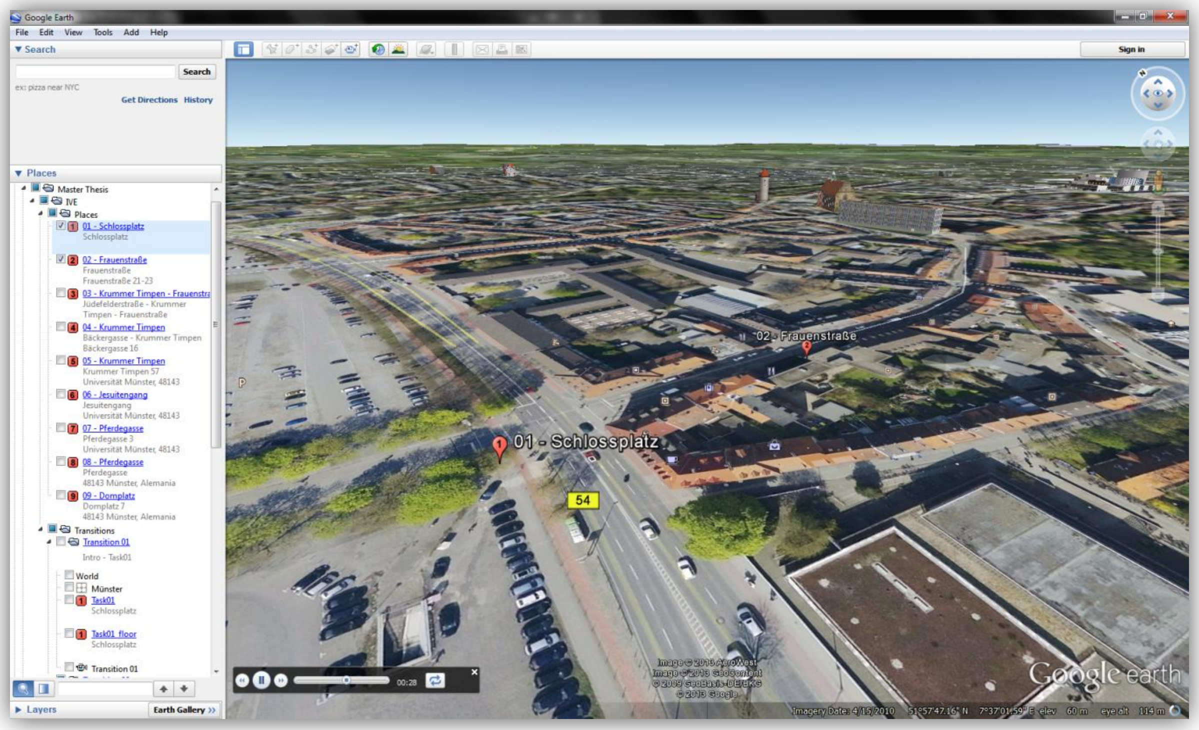


Image 4 - GE Tour of a transition

2.3. Evaluation setup

To properly evaluate our work, we have to make the user unaware of the system interface, architecture and usage. To achieve our goals we are going to select a set of places out of those contained in the system and create a video tour with a shortened version of the videos of the selected locations and the travel transitions in those locations. By doing this, we are isolating the transitions from the system so the knowledge of the user about the IVE becomes irrelevant.

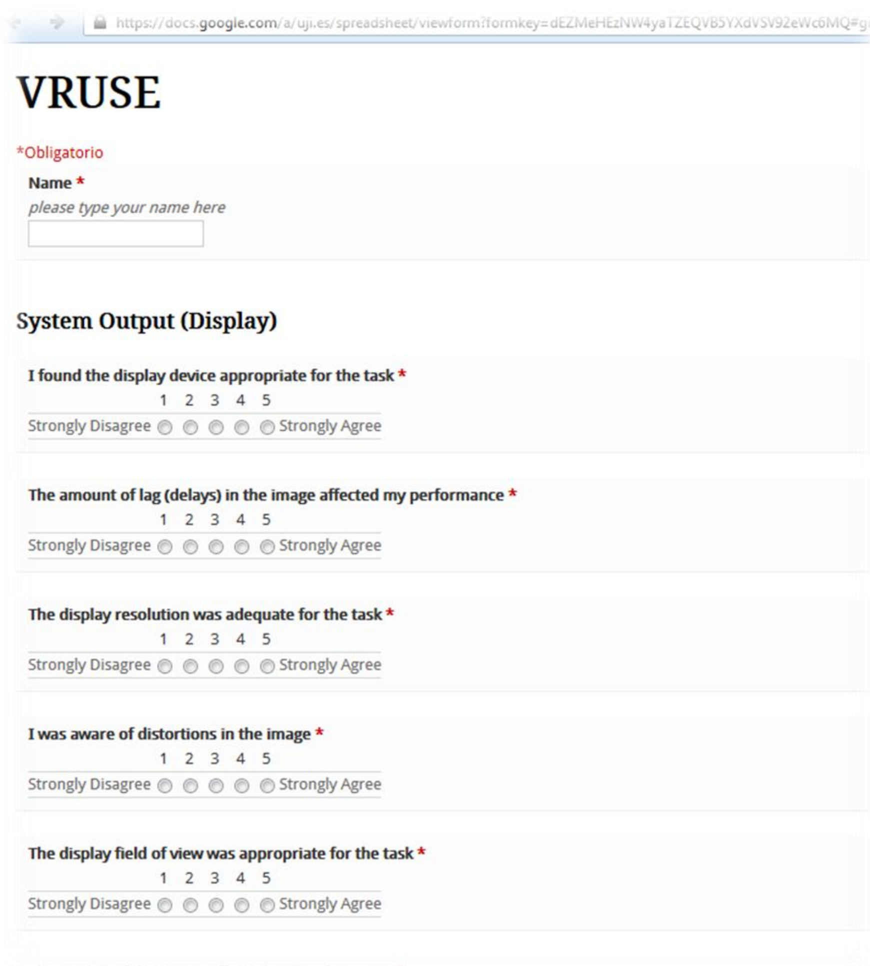
As stated earlier in this document, the quality factors affecting our selected travel technique are the **speed**, the **spatial awareness**, the **information gathering**, and the sense of immersion or **presence**.

In order to evaluate these factors we are going to use two different questionnaires and a short interview with each of the test users.

The first questionnaire (SSQ) measures the simulator sickness. It consists of two parts, one right before taking the tour and one before. It has been extracted from previous investigations [A07, A12] that demonstrated that people exposed to simulated motion can suffer from it. With this questionnaire we will evaluate the chosen speed.

The second questionnaire measures the system output, the simulation fidelity and the sense of immersion factors, corresponding to the information gathering, the spatial awareness and the presence respectively. The test takes place after the second part of the simulator sickness questionnaire. This test has been extracted from the VRUSE questionnaire, removing those parts that were irrelevant for our purposes.

Finally, a brief talk with the users after the experiment can provide some different feedback about their point of view and opinion.



VRUSE

*Obligatorio

Name *

please type your name here

System Output (Display)

I found the display device appropriate for the task *

Strongly Disagree 1 2 3 4 5 Strongly Agree

The amount of lag (delays) in the image affected my performance *

Strongly Disagree 1 2 3 4 5 Strongly Agree

The display resolution was adequate for the task *

Strongly Disagree 1 2 3 4 5 Strongly Agree

I was aware of distortions in the image *

Strongly Disagree 1 2 3 4 5 Strongly Agree

The display field of view was appropriate for the task *

Strongly Disagree 1 2 3 4 5 Strongly Agree

Image 5 - Example of an online questionnaire created using Google Drive forms

To ensure that users answer all questions contained in the tests and that there is no human error while collecting the data (entering the results in the computer for further analysis), we are going to create an online version of the questionnaires (Pre-SSQ, Post-SSQ and VRUSE) using the forms of the Google Drive [T13] technology. This technology provides a very simple and fast way to create forms and share them online, collecting automatically all results in a spreadsheet that can be easily exported to many formats. Our interest is to export them to CSV text documents that can be opened both with R and with MS Excel to manipulate and analyze the data and create diagrams to present and interpret our results.

2.3.1.SSQ

The SSQ [A13] evaluates a list of symptoms commonly experienced by users of VR systems. The reason to choose this questionnaire above any other is because it's considered the gold standard for measuring simulator sickness [A14]. They are evaluated with the scale from none, slight, moderated to severe (0-3). It is based on three components: nausea, oculomotor problems and disorientation, and they can be combined to produce a total SSQ score. All scores have their lowest level at 0, and they increase as the reported symptoms increase.

According to [A15], in VE the total scores usually average above 20, sometimes up to 50. For our system we are expecting scores around 25. Scores below 25 will indicate that the chosen speed is very good, scores between 25 and 50 indicate that the speed should be slightly reduced, and scores above 50 means either that the SISO speed is a bad choice or that the speed should be reduced considerably.

The list of symptoms and their weightings can be found at Table 2. To calculate the scores, we will use the table and the equations. First we calculate the total score for each of the three factors by multiplying the symptom scores by the weight and then calculating the sum for each column. The total score and the weighted scale scores for each of the column can be calculated using the following formulas:

$$Nausea\ Score = Nausea\ total * 9.54$$
$$Oculomotor\ Score = Oculomotor\ total * 7.58$$
$$Disorientation\ Score = Disorientation\ total * 13.92$$
$$TOTAL\ SCORE = (Nausea\ total + Oculomotor\ total + Disorientation\ total) * 3.74$$

Table 2 - SSQ weighting system

Symptom/Weight	Nausea	Oculomotor	Disorientation
General discomfort	1	1	0
Fatigue	0	1	0
Headache	0	1	0
Eyestrain	0	1	0
Difficulty focusing	0	1	1
Increased salivation	1	0	0
Sweating	1	0	0
Nausea	1	0	1
Difficulty concentrating	1	1	0
Fullness of head	0	0	1
Blurred vision	0	1	1
Dizzy (eyes open)	0	0	1
Dizzy (eyes closed)	0	0	1
Vertigo	0	0	1
Stomach awareness	1	0	0
Burping	1	0	0

Both questionnaires (pre and post exposure) contain the same set of questions. A printable version and the links to the online questionnaires are available in section 8.1.

Based on the profiled researched at [A14], the VE tend to produce more disorientation than nausea, and keeping the oculomotor scores as the lowest (D>N>O), while the profiles found for other environments were different: space sickness profile is O>D>N, and simulator sickness profile matches O>N>D.

2.3.2. VRUSE

The second questionnaire is a subset of questions extracted from the VRUSE [A09] questionnaire. As there is no interface between the user and the system, we have removed from the original test those questions about the interface, the error handling, the user input… and used the remaining 36 questions for our test.

Great care was taken to ensure that negative and positive bias questions was balanced, which is the reason why he have both negative and positive questions evenly distributed in the questionnaire.

All questions are rated from 1 to 5, being 1 the worst and 5 the best score. This is called the Likert scale. As there are both positive and negative questions, we need to fix the scores later to obtain the real scores by subtracting the score of the negative questions from 6.

The extracted questions are divided in 4 different sections: System output (Display), Information consistency, Simulation fidelity and Sense of immersion (Presence). The last question of each section allows the user to provide an overall rating of the section, from 1 (best) to 5 (worst). The first two sections evaluate the spatial awareness, the third one evaluates the information gathering and the fourth section evaluates the sense of immersion, also called presence. From each section we will obtain 2 different scores: the average and the overall scores. Ideally they should be the same, or at least very similar, for each user.

The average and overall scores are useful to get a general overview of the evaluation of each section, but to identify specific problems or flaws we have to check the answers to each question, starting by those with the lowest scores.

As our scores are based on the Likert scale, we are considering all scores above 3 as good. The scores below 3 are bad scores, and are indicators of a problem.

2.3.3. User group

To obtain significant results from the questionnaires we need a group of at least 4 persons, but to get better results (more homogeneous) we are going to test our prototype on 10 users.

The users selected are students from very different backgrounds (urban planning, social education, geography, computer science, institute…) and ages between 20 and 40. Most of them have never experienced any kind of IVE before.

The selection criteria was to call friends, fellow students and people working at IFGI in turns and ask them to volunteer as a test user.

It would have been desirable to have a bigger test group, but the time limitations to conduct this whole investigation wouldn't allow for it and we had to settle for 10. Still, this number is sufficient to get some significant results, though the variance of the answers

3. Travel Prototype

As we have previously stated, we are going to create a prototype of travel transition for our IVE, and we are going to evaluate our results. To evaluate our results we need the final user to appreciate the transitions in a context, so we are going to create a video tour containing both the transitions between places and the videos of those places in one single video file.

As the final size of the video would be around 200GB using the uncompressed video format of the original videos of the locations, we are going to use the Xvid codec to compress them without losing quality, but saving a huge amount of space, as the final size of the tour video is less than 1 GB.

3.1.1. Locations

As our IVE contains a set of videos of locations in Münster, we have selected 9 of them to make our tour. These places are all inside the Münster Zentrum (the center of Münster) and not far from each other. We can see a map of them in Image 7 (created in GE). The length of these videos is around 5 minutes, but we are going to shorten them to 90 seconds each to shorten the total length of the tour using AVC [T11]. There are two reasons to reduce the length of the videos to 90 seconds: the first reason is that they are too long for our purpose, and we want to center the attention in the transitions. The second reason is the reason why the videos aren't even shorter, which is that if we made them shorter the users would not have time to feel immersed. One and a half minutes is time enough for the user to watch around the simulated location and see a few people, cars, bicycles, etc. go by.

Image 6 - PlaceMarks of the visited locations

Each of the videos was recorded in a single spot, its coordinates were recorded using a high quality GPS, and the camera doesn't move at all during the video recording.

An example of one of these videos can be watched online at YouTube: http://youtu.be/bf0rFYW77xc. The links to the rest of the videos used can be found at section 8.3, along with the URL of the KML file with the PlaceMarks of the locations. These sample videos are the 40" version, not the 90" version used in the tour, as the 90" videos would unnecessarily take a bigger amount of space. It is also possible that the videos will not work (you will only see a green screen during all video) when selecting the highest resolution. The most likely reason is that YouTube cannot handle such a big width (5760px), as it's three times the FullHD width (1920px).

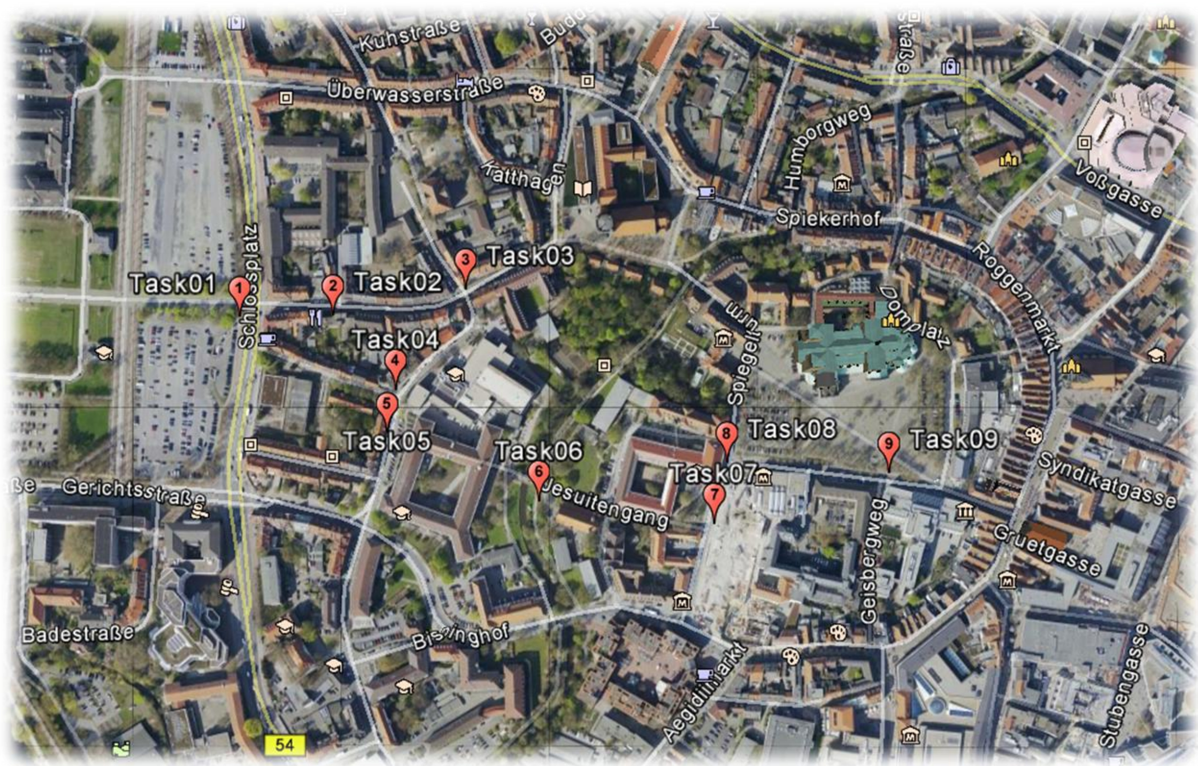


Image 7 - Map of the places visited in the tour

3.1.2. Transitions

To create the transitions, first we have created the PlaceMarks corresponding to the videos. As we had the coordinates but not the orientation, the orientation was fixed manually by comparing the video of each location with its Google Earth representation. Once we had the orientation of each place, we duplicated the PlaceMarks. For each place now we have two PlaceMarks, and each of them with a different view. One of the views resembles that of the video: the floor view (Image 10). The other view is the eagle view (Image 11), where you can see the Placemark from further away to give the user a better understanding of the surroundings.

Once we had both PlaceMarks for each place, we are going to create two more PlaceMarks: one with a view of the world and other with a view of Münster. They will be used for the initial and final transitions.

Now that we have all the PlaceMarks, we created a folder in GE for each of the 10 transitions, in which we pasted the PlaceMarks that will appear in each transition. All transitions contain 4 PlaceMarks. The first one starts with the world view, then Münster view, then the eagle view of the first place and finishes with the floor view. The last one is the same but in reverse order (floor view - eagle view - Münster - world). The rest of the transitions have a common structure: first the floor view of the origin place, second the eagle view of that same place, third the eagle view of the destination place, and finally the floor view of the destination place. The Image 8 shows an example of the directory tree created.

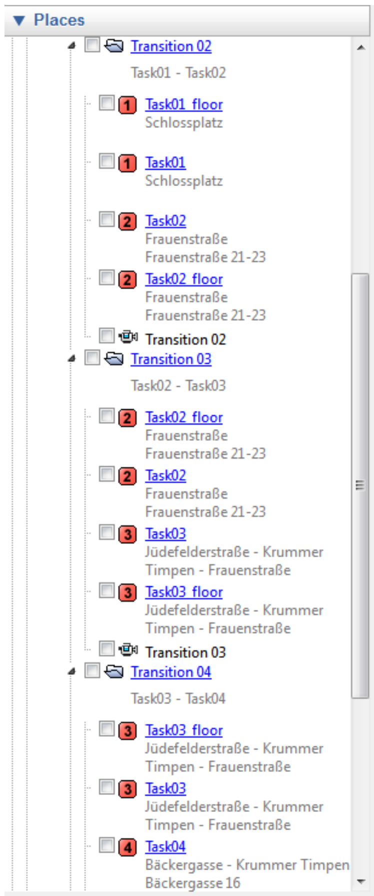


Image 8 - Directory tree of the transitions in GE

Once we have created all folders with the PlaceMarks ordered, we have to create a tour of each transition. To do so, first we tweak the GE touring options to adjust the speed, the total length of each travel between PlaceMarks and the time stopped on each one. With this we are making sure that the travel speed is neither too fast nor too slow. Also, the quality of the touring is raised to max quality to avoid jumps and get a smooth tour. With all this done, we can start creating the

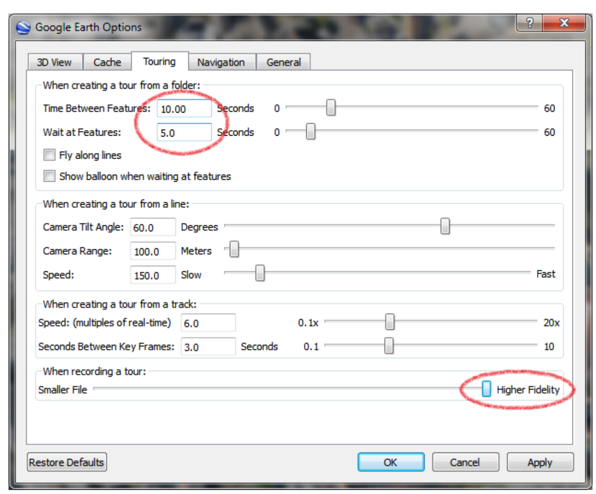


Image 9 - Google Earth options for the speed and quality of the tours

tours in Google Earth. To adjust the speed, we selected a 10 seconds travel between features (meaning PlaceMarks) and 5 second waiting at them, as we can see in Image 9.

To display some textual information of the surroundings, we will have activated the following layers in GE: Borders and Labels, Places, Roads, 3D Buildings and Local Place Names. The remaining layers are kept deactivated, as their information is unimportant for our purposes.

Image 10 - Example of Floor View of a travel transition

Image 11 - Example of Eagle View of a travel transition

To create the videos of the transition tours, we need GE Pro Movie Maker, and select the highest resolution possible: HD+ (1920x1080 px).

As the average resolution of the videos of the places is 5760x1080, we had to trim and resize the transition videos to match this resolution. To resize and trim the transitions, the Any Video Converter free version program [T11] was used. An undesired, but unavoidable, side effect of this operation is the loss of the upper and lower parts of the videos, where the compass, GE logo and copyright information were displayed.

A transition can be seen online at http://youtu.be/VBnQAZBXVI8. The links to the rest of the transitions and the URL to the KML file containing the transitions PlaceMarks and tours can be found in section 8.4.

Image 12 - Transition example: flying between PlaceMarks 07 and 08

3.1.3.Tour

The final result is a video tour containing the transitions and locations all in a single video file. What you can see in the video is a travel from a view of the world to Münster, and then to the first place we are going to visit (Schlossplatz). Then we can see the video of the first place. After 3 minutes, we see the transition travelling to the second place and the video of the second place after it and so on. After the last video of the locations is finished, the last transition zooms out to Münster and then to the Earth view, and there the tour ends.

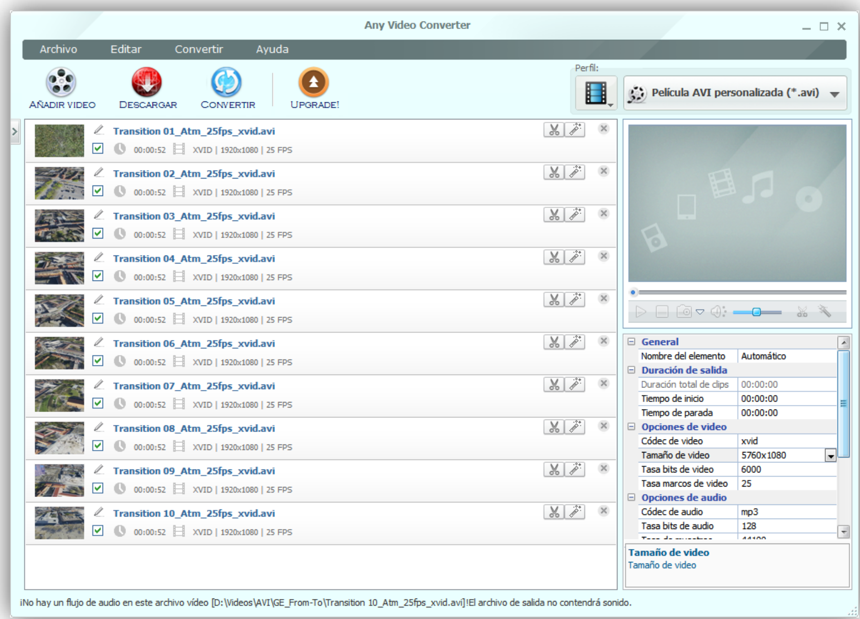


Image 13 - Conversion of the transitions videos with AVC

Previous to creating the final video, we will first process the videos of the locations and the transitions with AVC [T11]. The videos of the locations have similar but different resolutions, they are raw video (uncompressed) in AVI format, the resolutions range from 5760x1080 to 4948x904 @ 25fps, their duration ranges from 5'10" to 2'48" and they have audio track. Their size ranges from 7 to 16 gigabytes. The videos of the transitions are in WMV format, 1920x1080 @ 25 fps and no audio track. The duration is 52" and the size is close to 100 megabytes.

To create one video file containing all the pieces, first we need to have these pieces in the same format. We are going to convert all the videos to AVI files compressed in Xvid with a bit rate of 12k, to keep as much quality as possible, with a resolution of 5760x1080 @ 25 fps and no audio track. The videos of the locations will be cut down to 1'30". From the transitions we will remove the first and last 4 seconds. The final size of the IVE videos is around 67 megabytes, and the transitions' size is around 30 megabytes.

After converting all the pieces, we will join them together with the VirtualDub [T12] software.

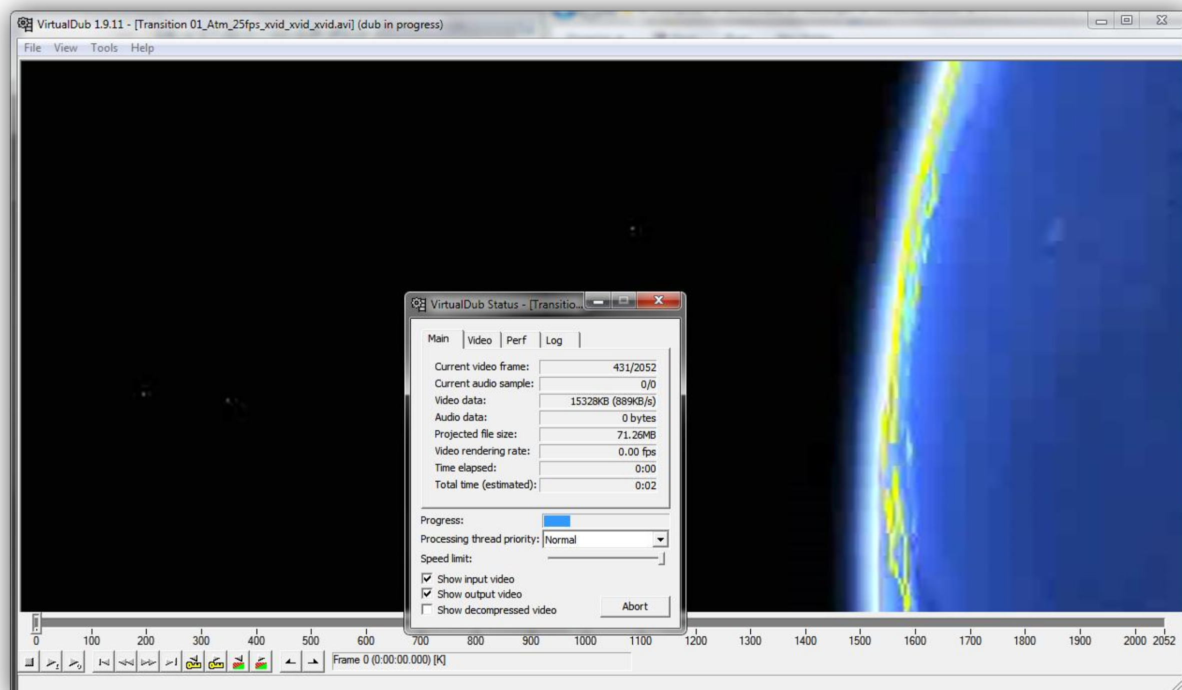


Image 14 - Joining the IVE videos and the transitions to create the tour using VirtualDub

The characteristics of the video tour file obtained as a result of this process are the following:

- Resolution: 5760x1080 pixels
- Frame rate: 25 FPS
- Size: 0.9 Gigabytes
- Length: 20 minutes
- File format: AVI
- Codec: Xvid

On the following URL we can watch an online version of the tour: http://youtu.be/VBnQAZBXVI8

4. Evaluation

The evaluation of the prototype is very important to assess its quality. As stated earlier in this document, we are going to measure four quality factors: speed, spatial awareness, information gathering and presence. The speed is measured with the SSQ, and the rest are measured with the VRUSE.

A group of 10 users were selected for the evaluation process. The people selected belong to very different backgrounds (urban planning, social education, geography, computer science, high school…) and their ages range between 20 and 40. Most of them have never experienced any kind of IVE before. The selection criteria was to call friends, fellow students and people working at IFGI, and ask them to volunteer as a test user.

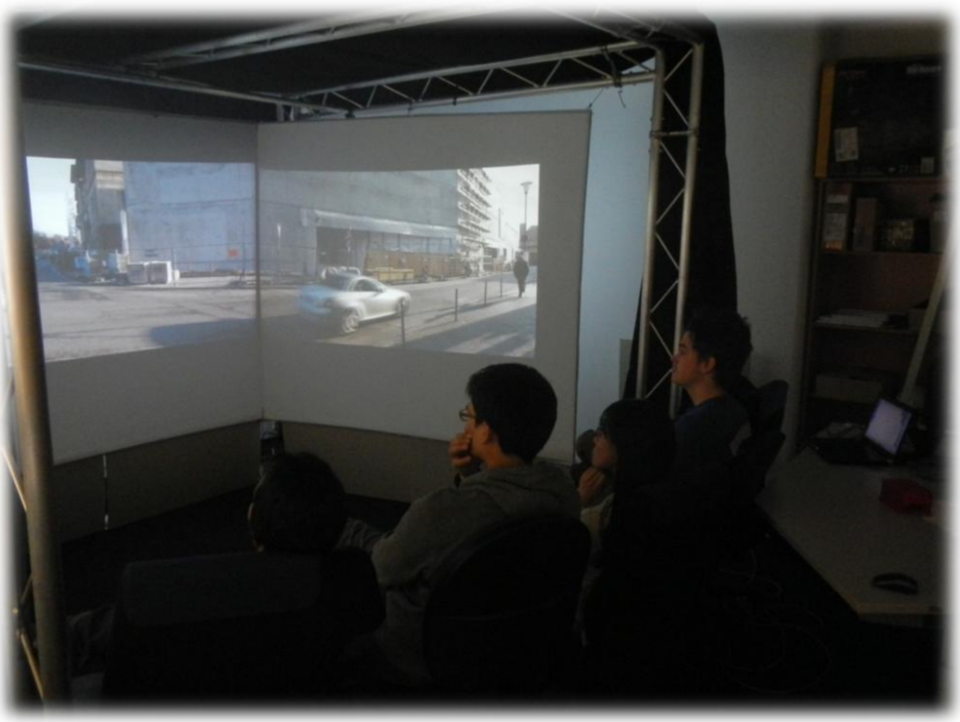


Image 15 - Group of users watching the tour during one of the evaluation sessions

The evaluation process was divided in three sessions, in groups of 3-4 persons, each session around 45 minutes long including the video and the three questionnaires (20 minutes for the video and 15-25 for the questionnaires).

The first questionnaire to be filled in by the test users is the SSQ, one time before (Pre-SSQ) and again after the exposition (Post-SSQ) to the IVE has finished. The questions are related to the symptoms the user feel at the precise moment the questionnaire is taken. Both questionnaires contains 16 questions. Each one takes 2-5 minutes to be completed. The URL to the online tests and a printable version can be found at section 8.1.

The second questionnaire is the VRUSE. It contains 36 questions, and takes from 10 to 20 minutes to be completed. It is the last questionnaire the users have to answer, right after the Post-SSQ. The questions in this questionnaire are technical questions related to the system and the simulation, and some users needed some help to understand the questions and fulfill it correctly. A printable version of the questionnaire and the URL to the online form can be found at section 8.2.

After each session, a brief informal talk with the users about the experiment took place, where they could give their opinions and remarks. Most of the users liked the system and the travel transitions, but the opinion that remained constant for all the users was that the test sessions took too much time. Also, some of the users agreed that the travel transitions would be considerably enhanced with more 3D buildings, as it would make the virtual world resemble the real world much more.

5. Results

This section is divided in two parts. The first part is dedicated to the presentation of the results obtained in the questionnaires. The second part contains the analysis and interpretation of the obtained results.

5.1. Presentation of results

The results obtained on the questionnaires will be presented by the use of tables, and the explanatory diagrams will be presented in the next section. We will show the scores already transformed and weighted per user and factor. The scores per user and question can be found in the annexes at the end of the document.

5.1.1. SSQ results

First we will see the mean results per user and total mean results of the Pre-SSQ questionnaire, then the Post-SSQ results, and after it the results of the difference between the post and the pre SSQ results. As a reminder, these tests are evaluating the adequateness of the speed technique used (SISO) and the speed itself. We are expecting a total score around 25, hopefully below it, and inside the range [0,50].

5.1.1.1. Pre-SSQ results

Below, at Table 3 we can see the scoring of each participant on the different factors measured by the SSQ and the total score. This test measures the state of the participants previous to the test. After it, Table 4 shows the mean and standard deviation of the scores of each factor and total.

It is usual to obtain very low scores in the Pre-SSQ (very close to 0), unless some external factor is affecting them, i.e. disease, tiredness...

The raw scores obtained by each participant in each question, already formatted to range from 0 to 3, can be found in a table at section 8.1.3.1.

Table 3 - Pre-SSQ scores

	Nausea	Oculomotor	Disorientation	Total
user01	0	0	0	0
user02	9,54	7,58	0	7,48
user03	19,08	37,9	27,84	33,66
user04	0	0	13,92	3,74
user05	0	15,16	13,92	11,22
user06	9,54	37,9	27,84	29,92
user07	9,54	45,48	27,84	33,66
user09	0	7,58	0	3,74
user08	19,08	37,9	27,84	33,66
user10	0	7,58	0	3,74

Table 4 - Pre-SSQ mean and SD of the scores

	Nausea	Oculomotor	Disorientation	Total
Mean	6.678	19.708	13.92	16.082
Standard Deviation	7.854	17.938	13.124	14.650

5.1.1.2. Post-SSQ results

The scores obtained per participant to each of the three factors and the total score on the Post SSQ test are at Table 5. After it, Table 6 shows the mean and standard deviation of the Post-SSQ scores. The raw scores, already formatted to range from 0 to 3, can be found at section 8.1.3.2.

Table 5 - Post-SSQ scores

	Nausea	Oculomotor	Disorientation	Total
user01	0	15,16	13,92	11,22
user02	9,54	37,9	27,84	29,92
user03	28,62	53,06	41,76	48,62
user04	0	0	0	0
user05	9,54	37,9	55,68	37,4
user06	38,16	68,22	69,6	67,32
user07	9,54	37,9	41,76	33,66
user09	0	7,58	13,92	7,48
user08	19,08	30,32	27,84	29,92
user10	9,54	15,16	0	11,22

Table 6 - Post-SSQ mean and SD of the scores

	Nausea	Oculomotor	Disorientation	Total
Mean	12.402	30.32	29.232	27.676
Standard Deviation	12.760	21.140	23.154	20.726

5.1.1.3. Post-SSQ minus Pre-SSQ results

Below we will find the scores corresponding to the Post-SSQ after subtracting the results obtained in the Pre-SSQ. This scores are very useful to compare both the Pre-SSQ and the Post-SSQ scores in order to draw conclusions and find reasons to explain the obtained results.

These scores have been calculated by subtracting the final results, already weighted, and not the partial results shown at section 8.1.3, but the results obtained would be the same.

Table 7 shows the results per user on each of the three factors measured and the total score. Unlike in the Pre- and Post-SSQ, it is possible to find negative numbers in the scores. The meaning of those values will be explained later in section 5.2. Table 8 shows the mean and standard deviation of the scores.

Table 7 - Diff. Post-Pre SSQ scores

	Nausea	Oculomotor	Disorientation	Total
user01	0	15,16	13,92	11,22
user02	0	30,32	27,84	22,44
user03	9,54	15,16	13,92	14,96
user04	0	0	-13,92	-3,74
user05	9,54	22,74	41,76	26,18
user06	28,62	30,32	41,76	37,4
user07	0	-7,58	13,92	0
user09	0	0	13,92	3,74
user08	0	-7,58	0	-3,74
user10	9,54	7,58	0	7,48

Table 8 - Diff. Post-Pre SSQ mean and SD of the scores

	Nausea	Oculomotor	Disorientation	Total
Mean	5.724	10.612	15.312	11.594
Standard Deviation	9.217	14.382	17.911	13.708

5.1.2. VRUSE results

The VRUSE questionnaire scores are divided in 4 different sections. The first two sections, display and information consistency, are used to evaluate the second quality factor: the information gathering. The third section, simulation fidelity, evaluates the third quality factor: the spatial awareness. Finally, the last section of the VRUSE, presence, evaluates the fourth and last quality factor: the sense of immersion. The scores obtained are based on a Likert scale, 1-5, meaning that scores above 3 are positive while scores below it are negative and indicators of problems or flaws in our system.

To present the data collected from the questionnaires we will use three tables. The first of them is Table 9. It contains two scores per user per section, one is the average of the questions of that section and the second is the overall score of that user to the section, and an average of the total and overall scores.

Table 9 - VRUSE scores

	user 01	user 02	user 03	user 04	user 05	user 06	user 07	user 08	user 09	user 10
Total	4,02	3,67	3,70	4,58	3,32	3,78	3,65	3,73	4,00	3,40
Overall Total	2,75	2,75	3,75	5	3,25	4	2	4,5	3,75	2,25
Display	3,93	3,93	3,67	4,93	3,67	3,07	3,87	3,67	4	3,47
Overall Display	3	2	4	5	3	4	2	4	4	2
Consistency	4	4	4	5	3	4	4	4	4	3
Overall Consistency	2	2	3	5	3	4	2	4	4	2
Simulation Fidelity	4,35	3,88	3	4,63	3,13	3,38	3,38	3,75	4,13	3,5
Overall Simulation Fidelity	4	4	4	5	3	4	2	5	4	2
Presence	3,88	2,88	4,13	3,75	3,5	4,63	3,38	3,5	3,88	3,63
Overall Presence	2	3	4	5	4	4	2	5	3	3

The next two tables show the mean and standard deviation of the scores per section: Table 10 the total scores and Table 11 the overall scores.

Table 10 - VRUSE mean and SD of the general scores

	Display	Information consistency	Simulation fidelity	Presence	Total
Mean	3.821	3.9	3.713	3.716	3.784
Standard Deviation	0.477	0.568	0.534	0.468	0.356

Table 11 - VRUSE mean and SD of the overall scores

	Display	Information consistency	Simulation fidelity	Presence	Total
Mean	3.3	3.1	3.7	3.5	3.4
Standard Deviation	1.059	1.101	1.059	1.080	0.973

The scores of each participants to the questionnaire, already formatted so 1 is the worst result and 5 the best, can be found in the annexes, section 8.2.3.

5.2. Discussion of results

Now, with the help of some diagrams to aid us visualize the data previously presented, we will analyze the scores obtained and try to reach some conclusions about it. Again, we will start with the results obtained in the SSQ questionnaires to evaluate the first quality factor: the speed. Later we will continue with the VRUSE results that evaluate the other three quality factors: Information gathering, spatial awareness and sense of immersion.

It is important to notice that the standard deviation in most cases is remarkably high as a consequence of the smallness of the test group, and thus no significant results can be obtained from it, so we will focus mostly on the mean scores leaving the standard deviation aside.

5.2.1.SSQ - Quality Factor 1: Speed

As mentioned before, this questionnaire measures simulation sickness using three factors and a total score. The reason to run this questionnaire twice (Pre and Post exposure) is to identify the symptoms that participants may present before the exposure. This way we can reduce the influence of outside factors, like tiredness after several hours working or after sports, or identify them to take them into account.

For virtual environments like ours, the average total scores usually range from 20 to 50. For our particular case we are expecting scores around 25 (represented in the diagrams with a red line) and inside a range from 0 to 50 (represented by the blue lines). To easily visualize the results, we are using boxplots and histograms.

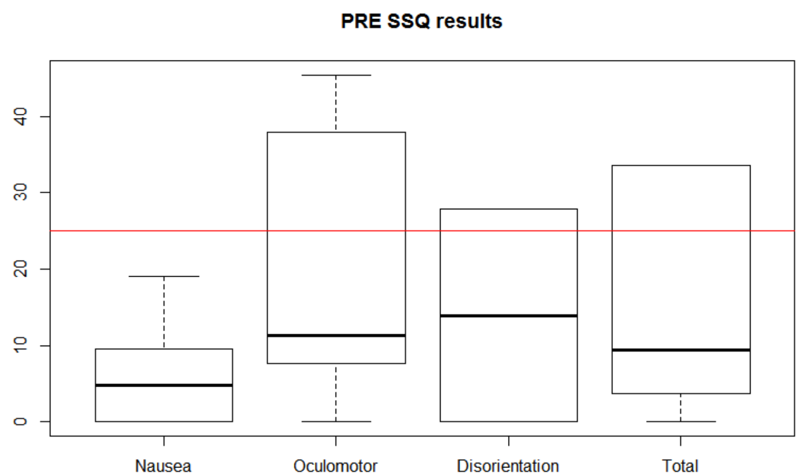


Figure 3 - Boxplots of the Pre-SSQ scores

For the Pre-SSQ, usually most scores are 0. We can see in Figure 3 and Figure 4 that this is not our case. In Figure 3 we notice that the Oculomotor scores are very high, and also the disorientation scores. In their corresponding histograms (Figure 4) we can see that 4 participants have rated very high in both cases, producing the unexpectedly high outcome.

Those four participants that rated so high in the Pre-SSQ claimed to be very tired when they participated in the evaluation session due to long hours working in front of a computer screen and lack of sleep. That would explain their scores. Also two of those participants had come hurriedly by bicycle to the session, adding physical tiredness to their symptoms.

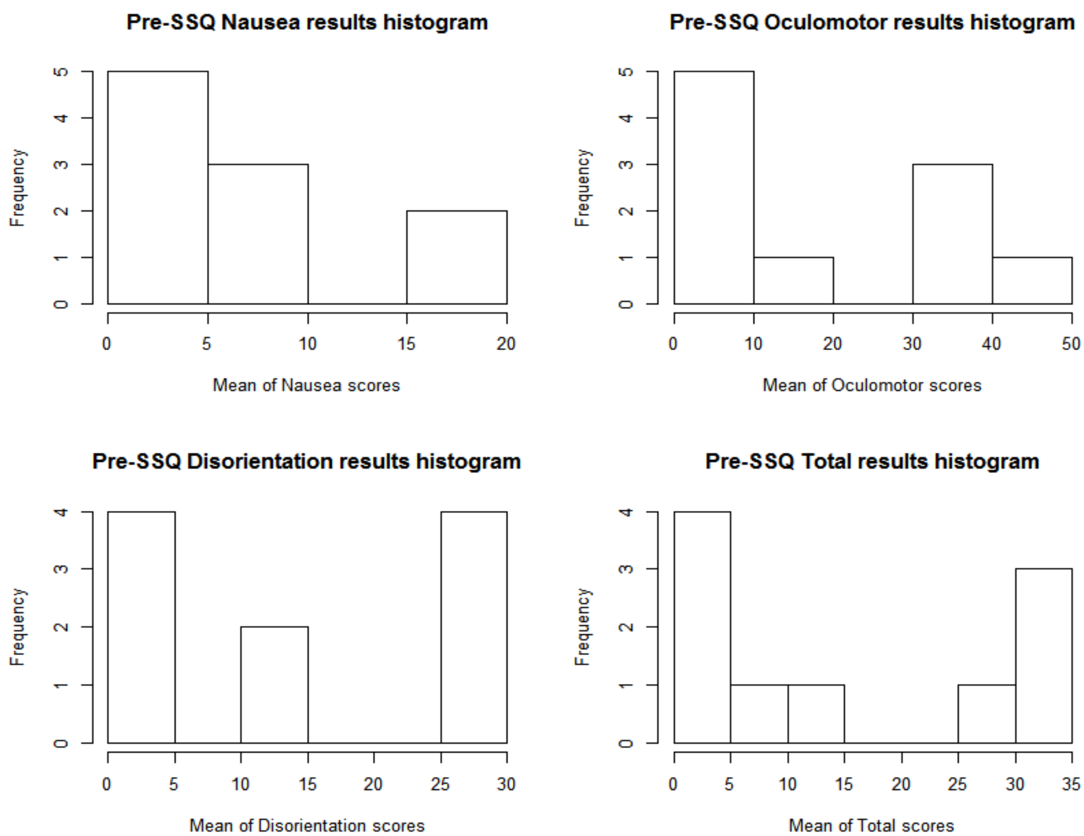


Figure 4 - Histograms of the Pre-SSQ scores

The oculomotor and disorientation symptoms reported by those four participants (general discomfort, fatigue, headache, eyestrain, difficulty concentrating, difficulty focusing, fullness of head and blurred vision) are among the symptoms associated with physical and mental tiredness, caused by sports and prolonged expositions to computer screens and intellectual work respectively. Taking this into account we can make the hypothesis that their tiredness was the reason for scoring high in the pre-exposure test.

If we take a look at the post-exposure results displayed in Figure 5 we can see that the scores have increased considerably: Nausea has increased by an 85%, Oculomotor by a 53%, Disorientation by a 110% and the Total by a 72%.

By comparing the Nausea histogram in Figure 6 it with its pre-exposure equivalent (Figure 4), we can see that, despite the fact that nausea has reported an increase of an 85%, this is due to a very small part of the participants, and still 70% of the participants scored below 10.

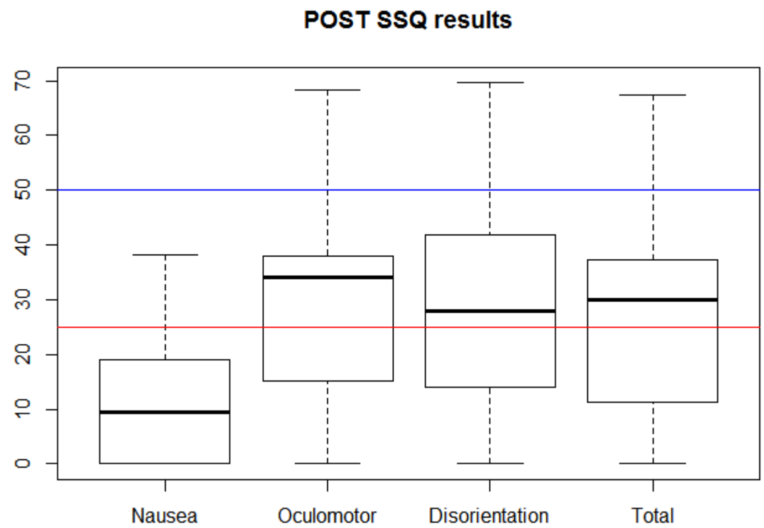


Figure 5 - Boxplots of the Post-SSQ scores

But to best compare the results obtained in the pre- and post-exposure questionnaires, we have subtracted the scores in the pre-exposure questionnaire to those of the post-exposure.

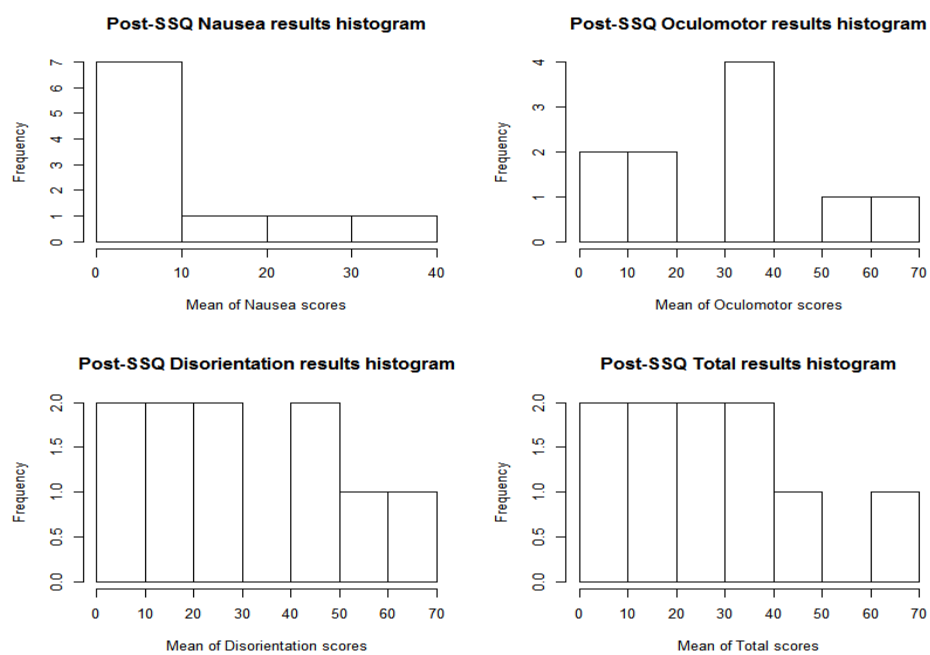


Figure 6 - Histograms of the Post-SSQ scores.

At Figure 7 we can see the real symptoms produced by the simulation are not as high as we feared: all the scores obtained are inside our expected range (<50), and, with a few exceptions, most of the scores were below our expected score (25).

In the case of the nausea, the effects were barely noticed by the participants with the exception of one participant.

On the other hand, the cases of the oculomotor and disorientation subscales scores require some explanation to understand the negative scores.

We can see in the oculomotor and disorientation histograms (Figure 8) that 4 and 3 participants have rated 0 or below. As it is obvious that the exposition to our system is not a cure to those symptoms, it is reasonable to assume that the same participants that scored so high in the pre-exposure questionnaire, theoretically by tiredness, have rested and relaxed during the 20 minutes they spent watching the tour video, and thus their symptoms have reduced.

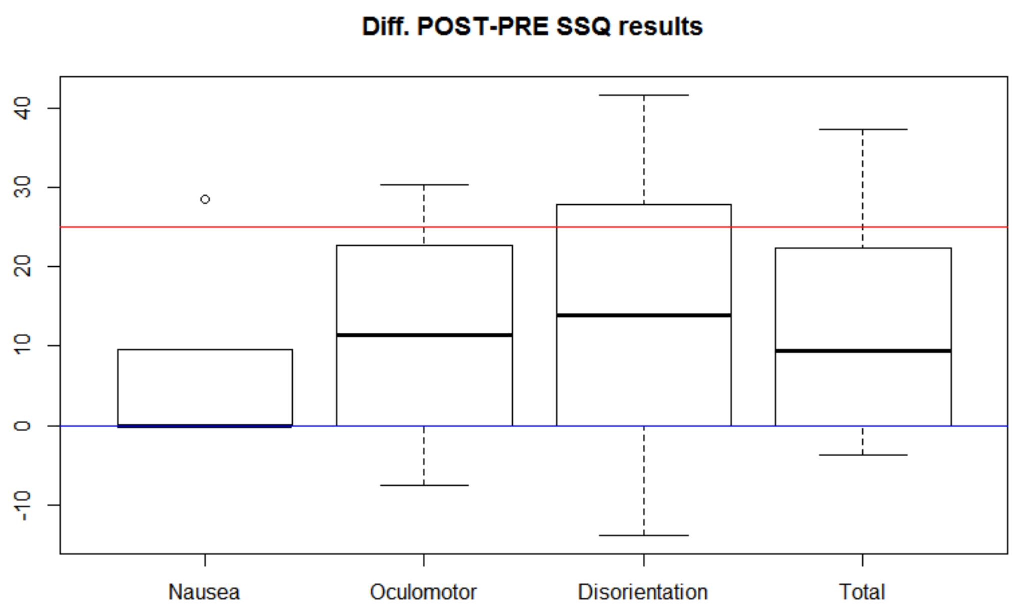


Figure 7 - Boxplots of the Post-Pre SSQ scores

Our purposes with this questionnaire are evaluating the travel technique (SISO) and the speed, associated with the Total and Disorientation subscales respectively, so now that the scoring has been explained, we are going to focus in the scores obtained in those two subscales.

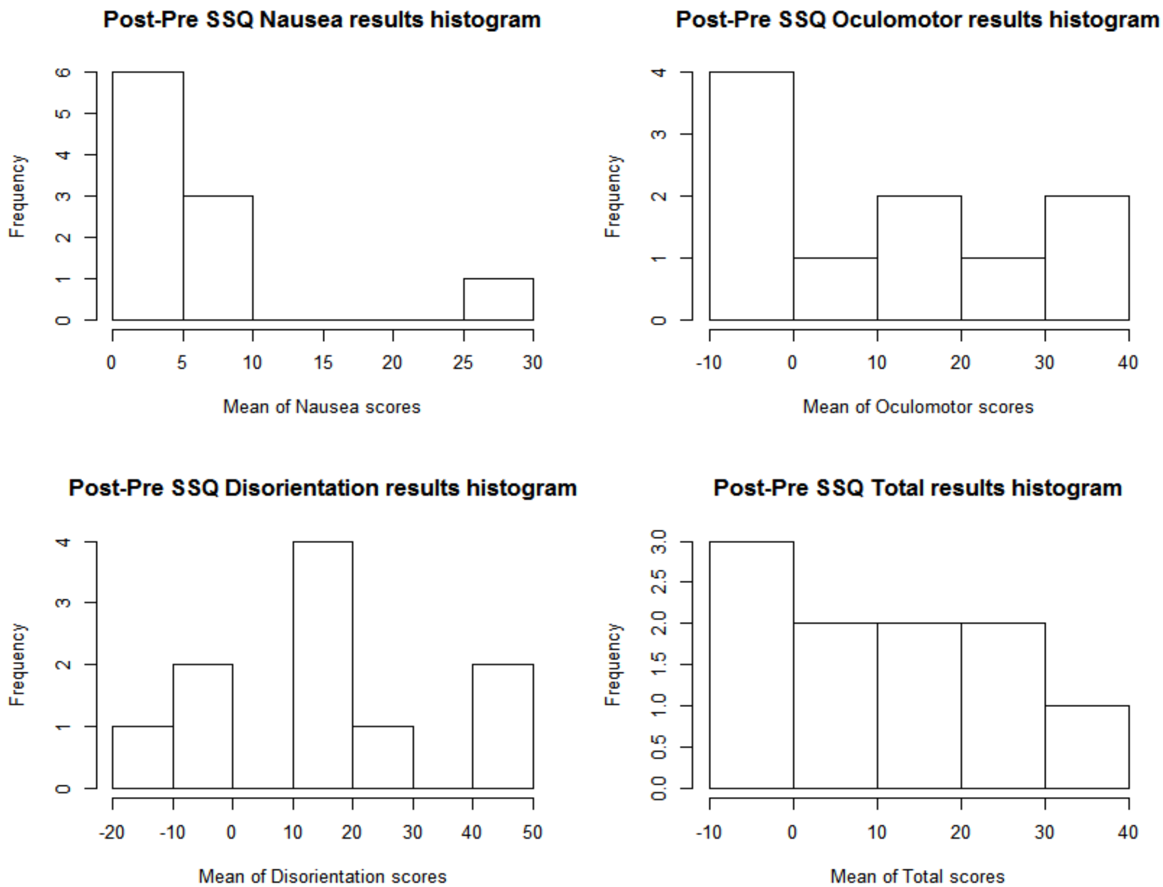


Figure 8 - Histograms of the Post-Pre SSQ scores

In the Disorientation results histogram (Figure 8) we can see that 70% of the participants have scored less than 25, almost half of those scores being 0 or less, a 10% scored close to it, and the remaining 20% scored considerably above it but still in range. The **average Disorientation score is 15,3** (sd=17,9). This is a very good score, concluding that the chosen speed for the travel simulations is very adequate for our system.

In the Total results histogram, at Figure 8, and the Total scores, at Table 7, we can see that every participant has rated below our expected outcome, with the exception of 1 that rated slightly above it. The **average Total score is 11,6** (sd=13,7), a very good result and better than expected, proving the SISO speed technique to be very good for our purposes.

An interesting fact found is that the profiles obtained for the pre- and post-exposure matches the space sickness profile (O>D>N) instead of the VE profile (D>N>O), but the VE profile was obtained using HMD.

5.2.2. VRUSE

As mentioned earlier, the VRUSE questionnaire is divided in four sections and evaluates the quality factors 2, 3 and 4. It is based on a Likert scale (1 to 5), and all scores above 3 are positive, which is what we are expecting. Each section is rated by a total and an overall score.

A possible bias was found for the overall scores, and will be explained in section 5.3.

5.2.2.1. Quality Factor 2: Information Gathering

The second quality factor, the information gathering, is evaluated by the first two sections of the VRUSE questionnaire: the Display (or System Output) and the Information Consistency.

As we can see on Figure 9 the system output has obtained very good total scores, all of them positive: 70% of them scored very close to 4 and a 10% scored almost 5. The average Display total score is 3,8 (sd=0,4). On the other hand, the average Display overall score is considerably lower: 3,3 (sd=1,06), with a 70% of positive scores. We can also notice that the total scores obtained are very similar, as 70% were between 3,45 and 4.

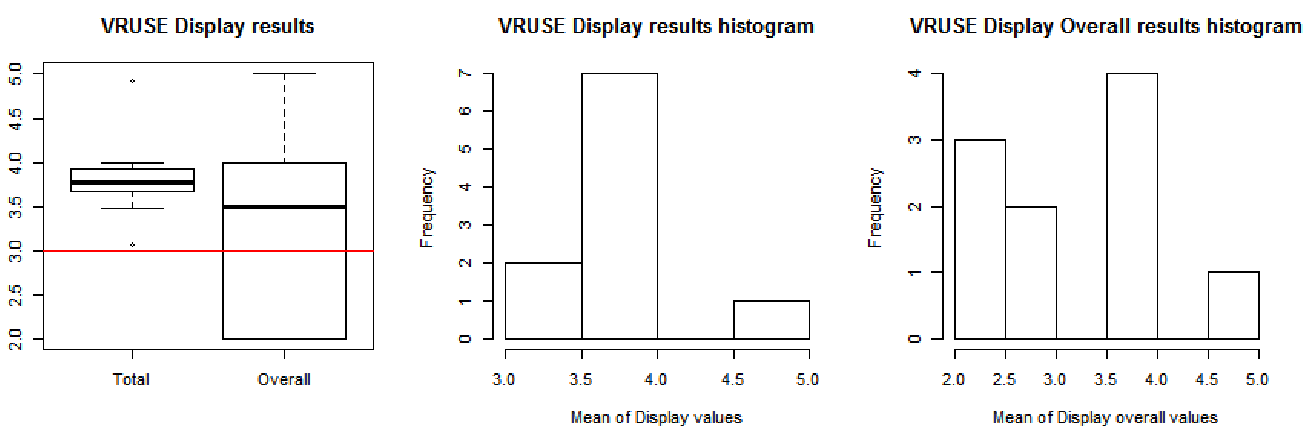


Figure 9 - Boxplots and histograms of the total and overall scores in the Display section of the VRUSE questionnaire

The scores obtained in the information consistency section are displayed in Figure 10, where we can see that 70% of the participants have scored 4 in the total results with a 100% of positive scores. The average Information Consistency total score is 3,9 (sd=0,6). Again, as in the previous section, we have considerably lower overall scores: 3,1 (sd=1,1), as 40% of the participants scored negatively with a 2 (the rest scored 3 or more).

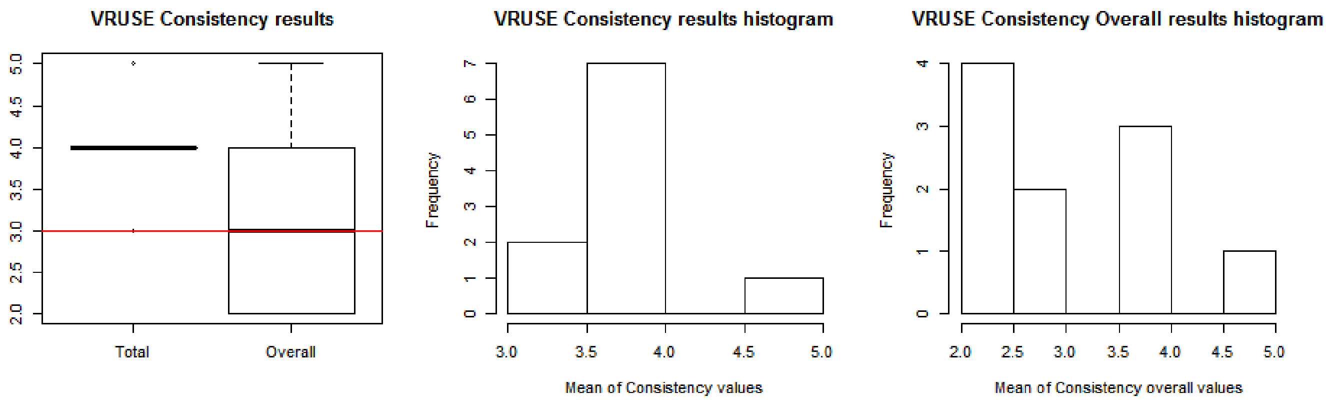


Figure 10 - Boxplots and histograms of the total and overall scores in the Information Consistency section of the VRUSE questionnaire

To rate the second quality factor we are considering the average of the total results on both sections, so **the Information Gathering score is 3,86**. Considering that all the participants provided positive scores, we can consider this result as an indicator that we are on the right way, but we can still make it better.

After checking the scores obtained at each question, we noticed that 50% of the participants reported distortions in the images (Q3), at Q2 a 20% reported lags (Q2) and at a 30% reported uncomfortable eyes (Q10). A 10% of the participants reported difficulty getting used to the display (Q12).

As the rendering of the simulation' graphics was performed previous to the creation of the video, and not on the moment of the exposition to the users, there were no distortions there, but the screens where the image is projected are soft screens, and air currents can easily bend them producing distortions.

About the lag reported, some more investigation needs to be performed there to find the reasons that produced those answers, because we didn't notice any.

5.2.2.2. *Quality Factor 3: Spatial Awareness*

Below, at Figure 11, we can see the graphics representing the scoring of the third section of the VRUSE questionnaire. In the histograms we can see that 100% of the participants' total scores were positive in the total score, and 80% of them in the overall score. The mean total score obtained is 3,7 (sd=0,5), and the mean overall is 3,7 (sd=1,06). It is a good indicator that both the total and the overall scores are the same. **The Spatial Awareness score is 3,7**.

By looking at the scores to the questions composing this section, we find that 40% of the participants considered the simulation too simplistic (Q20), 20% perceived the movement as unnatural (Q22) and 20% wanted more control over the simulation (Q24).

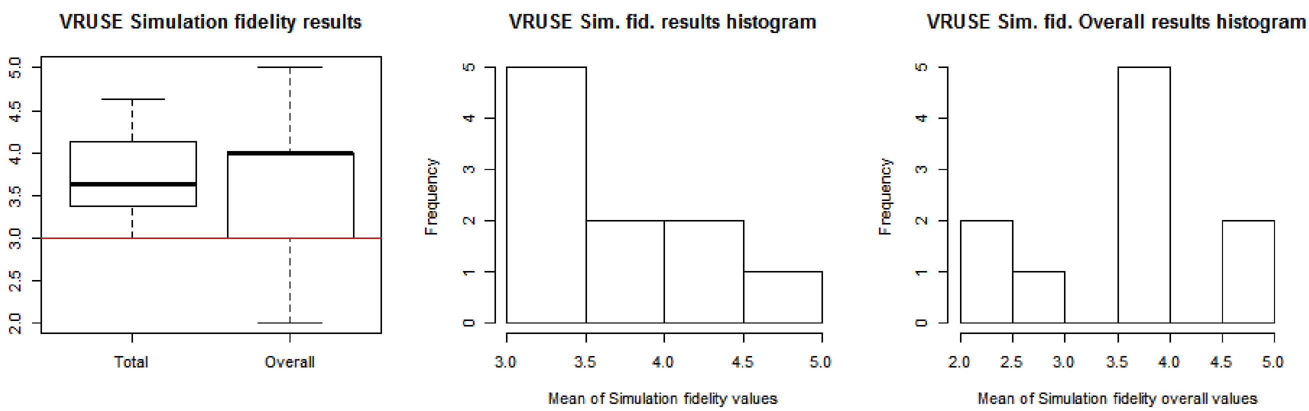


Figure 11 - Boxplots and histograms of the total and overall scores in the Simulation Fidelity section of the VRUSE questionnaire

5.2.2.3. *Quality Factor 4: Sense of Immersion*

At Figure 12 we can see the scoring of the 4th section of the VRUSE: Presence, which evaluates the sense of immersion. The total scores boxplot shows that the scoring of the participants to this section was very similar, as 80% are between 3,5 and 4,13. The mean total score is 3,7 (sd=0,47) the overall score is 3,5 (sd=1,08). As always, we use the total score for the evaluation, so **the Sense of Immersion score is 3,7**.

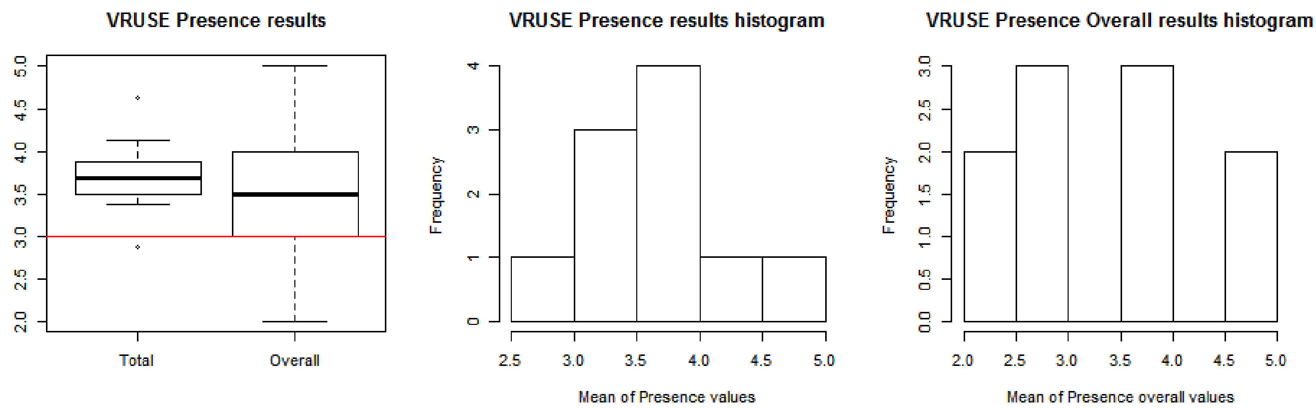


Figure 12 - Boxplots and histograms of the total and overall scores in the Presence section of the VRUSE questionnaire

The scores to the questions show that a 30% of the participants often did not know where they were in the virtual environment (Q35) though those same participants reported absolutely no disorientation (Q23).

5.3. Bias correction

As the results obtained in the Post-SSQ were much higher than expected, some more research was performed, and an article [A16] was found explaining that using both Pre- and Post-SSQ questionnaires seems to increase the reported motion sickness approximately by an 80%! And the reasons are 2: first, that you are informing the user about a set of symptoms he might suffer beforehand, and thus leading the user to focus on those symptoms and exaggerate them involuntarily. The second reason is that the user is induced to report a difference in the symptoms when facing the Post-SSQ test. This is called the Reporting Bias. If we take this into account, our average total score of 27.676 in the Post-SSQ could have been 5.535, and the disorientation score could change from 29.232 to 5.846.

In the case of the VRUSE we also noticed unexpected scorings, mostly in the overall results. The total and the overall scores of each user were expected to be similar, but as we can see at Table 9, in several cases the scores were quite different. It was also expected some degree of similarity in the scoring of the participants for each section.

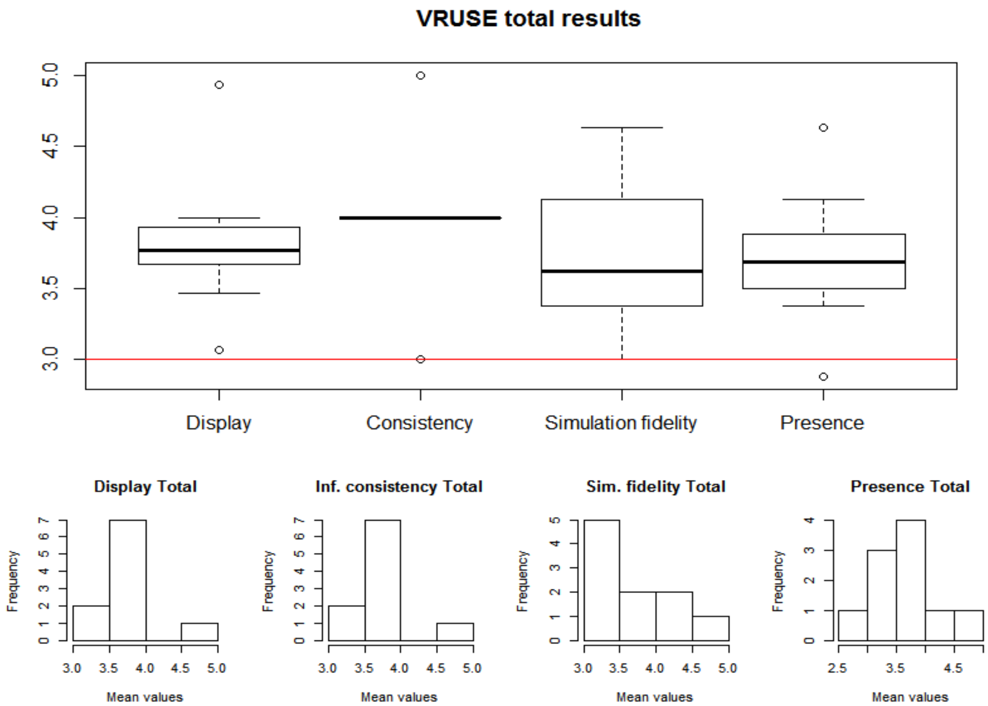


Figure 13 - Boxplots and histograms of the total scores obtained in each section of the VRUSE questionnaire

If we take a look at Figure 13 to visualize the total scores, we can see that the main body of the boxplots is not very big, and in the histograms we can notice at first glance that, in every case, 70% of the scores are inside a 1-point range and all the scores are within a 2-point range. On the other hand, the overall scores (Figure 14) follow a very different pattern: the main body of the boxplots is much bigger, and in the histograms we can see that only in the Simulation Fidelity overall score we have a 70% of scores inside the 1-point range, and in all cases the scores are in a 3-point range.

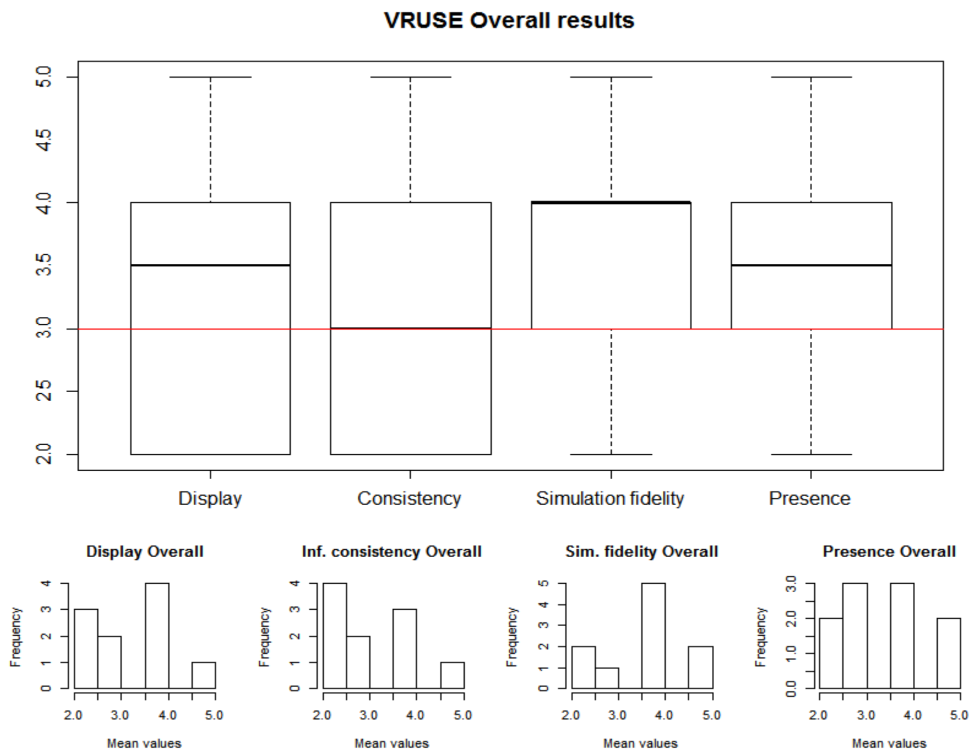


Figure 14 - Boxplots and histograms of the overall scores obtained in each section of the VRUSE questionnaire

If we take a closer look at the histograms of the overall scores in Figure 14, we can see another trend: in all sections there are at least two participants scoring negatively with a 2. To further analyze this anomaly we are going to compare the total and overall scores per participant.

At Figure 15 we can see that the overall scores of participants 07 and 10 are all negative and completely different from their total scores. The overall scores of participants 01 and 02 are also different from their total scores.

The most extreme case was participant 07. When we compare his total scores with the overall scores at Table 9, we can see that he always scored 2 where the was expected to score 4 or, at least, 3, and the same situation happens with participant 10.

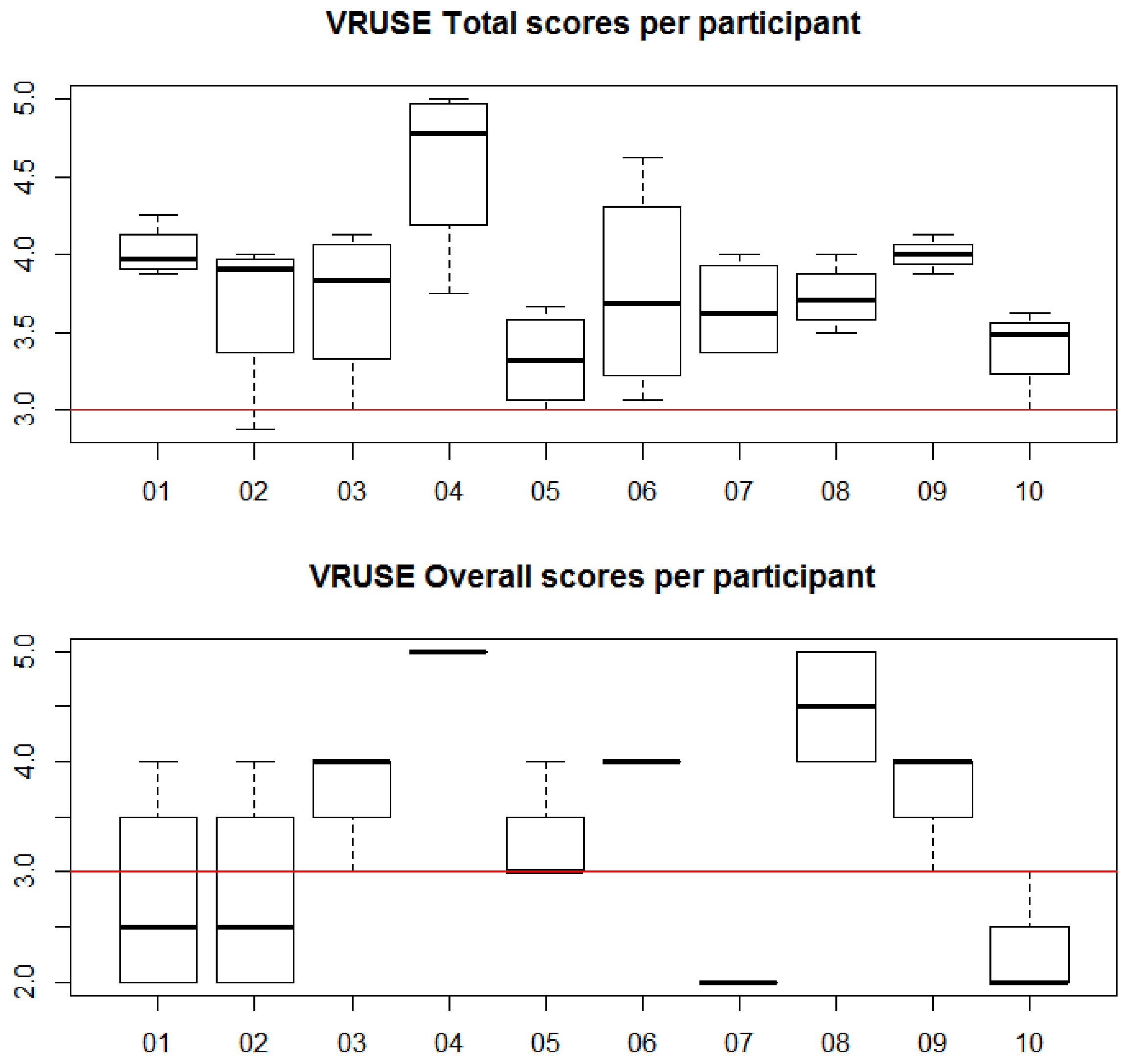


Figure 15 - Boxplots of the total and overall scores obtained per participant in the VRUSE questionnaire

After noticing this trend, it is possible to assume that they intended to score 4 but, for some reason, they scored 2. To find out why, we checked again the online version of the VRUSE questionnaire and found that, in the "Overall" questions, the scale was reversed from the rest, and a participant eager to finish might have easily overlooked that and provide the answer in the same scale. In the case of participants 01 and 02, it is likely that they realized the scale change in some cases but not in others.

Now, if we correct the hypothetically mistaken overall scores for those four participants, the situation changes drastically.

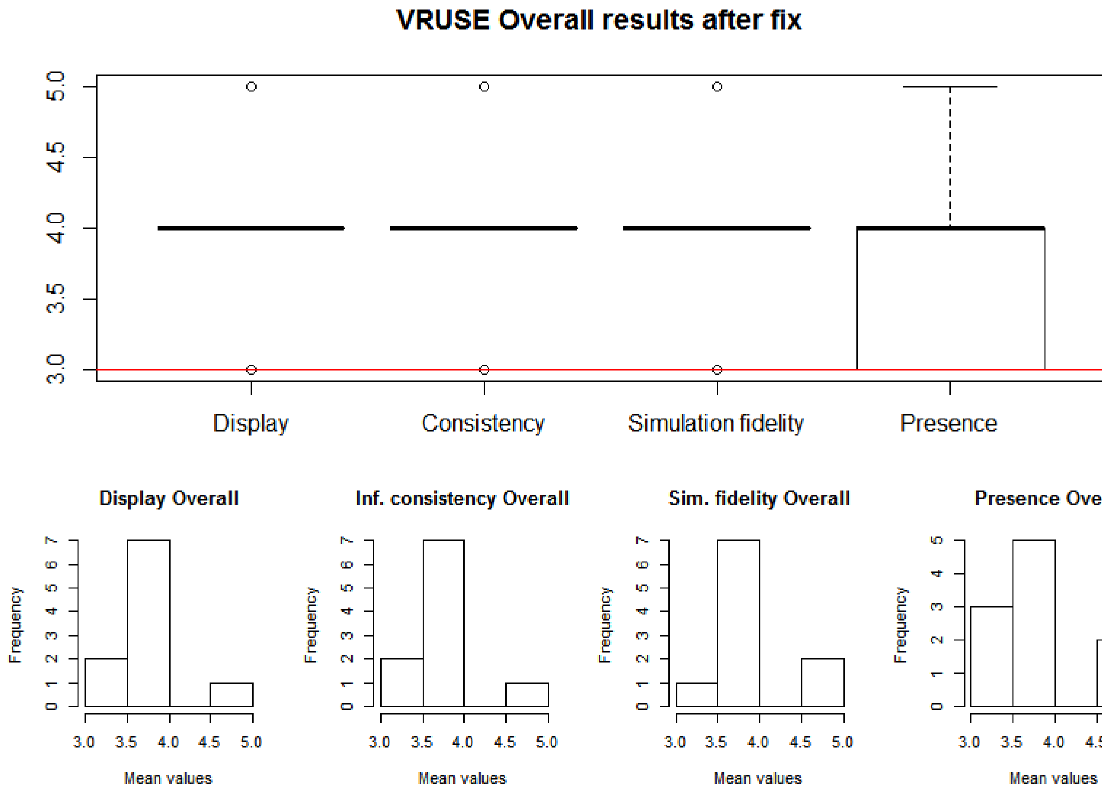


Figure 16 - Boxplots and histograms of the VRUSE overall scores after correcting the mistaken scores

As we can see at Figure 16, after correcting the mistaken values we have at least a 70% of the scores inside a 1-point range and all the scores inside a 2-point range. At Table 12 we can see that now the means and standard deviations of the overall scores are close to those of the total scores.

Table 12 - VRUSE mean and standard deviation of the overall scores after correcting the mistaken scores

	Display	Information consistency	Simulation fidelity	Presence
Mean	3.9	3.9	4,1	3,9
Standard Deviation	0,568	0,568	0,568	0,738

6. Conclusions

The usage of the Google Earth technology has demonstrated being a very powerful and flexible technology, and, even with its limitations, it was possible to provide a useful solution to our problem. Applying this technology to our problem, travel simulation, has provided a high level of realism while minimizing the costs in terms of efforts and resources. Also, considering the global acceptance, the growing rate and the size of the community behind it, the quality, functionality and flexibility of this tool will give us very nice surprises in time to come.

Although the results obtained are very good, the reduced size of the tested group, and the problems encountered during the evaluation and the analysis of the results, are clear indicators that there is need for a more exhaustive evaluation, and some issues to be solved before we can reach to a definitive conclusion. Still, the results obtained from the evaluation of our prototype are meaningful enough as an indicator that we are on the good way.

One of the problems underlying a more exhaustive evaluation is the difficulty to compare our results with the results obtained for other similar systems, as the specific characteristics of our IVE are unique. To further extend our evaluation we will need to use a gruesome amount of participants and test different exposure times, speeds and travel techniques to get a definitive travel simulation setup for our IVE system.

The final conclusion is that, by using the current available technologies, and taking into account the quality and usability factors affecting our system, we can successfully create travel transitions for an IVE with the characteristics identified in the Prototype Analysis section (2.1.4). The most important factor to achieve this goal is to closely analyze the IVE characteristics (aim, users, expectations, etc.) and correctly find the quality factors that are relevant to each case.

As a side effect we have started demonstrating what was guessed in [A10], which is that the bad scores obtained for the SISO speed may have been in the implementation: we have used one of the most globally accepted SISO engines used, Google Earth, and obtained excellent results in the speed factor. Still, a comparison of speed techniques would have to take place in our system before we can make such an statement.

6.1. Future work

The next step would be to integrate the transitions in our IVE. To accomplish this goal, many things should be changed in our system. First, the orientation of the videos should be also recorded along with the coordinates. The date and time the video was recorded should be added too, and also the city in which it was recorded. Of course, we would also need to link the transitions and the places accordingly.

Currently, the GE API doesn't have enough functionality to implement a program to generate the transitions automatically, and there is no clue about when will it be developed enough. If we want to avoid creating manually all possible transitions between every two places in our system, which would be wise because the number grows exponentially, there is another solution. This solution makes the integration of the transitions into the system a bit more complex, but is an elegant solution until the generation of transitions can be performed automatically. Basically, instead of one transition between two places, there would be two transitions per place: one before the video displaying the travel from the overview of the city where the video was recorded to the place the video was recorded. The second one is after the video and simulates the opposite travel. If there are videos from several cities, the same thing should be one for cities: travel from the overview of the country to the city and the opposite travel. This transitions for cities would appear only when the destination place is in a different city. The same thing should be done for countries: from the world overview to the country overview and the other way around.

With this system, the transitions would be displayed as in the following example:

Imagine a tour where we go first to the Eiffel Tower, then to the Berlin DDR Museum, then to Münster Domplatz and finally to the IFGI building. The system should display the following videos:

1. Transition: World -> France
2. Transition: France -> Paris
3. Transition: Paris -> Eiffel Tower
4. Video: Eiffel Tower
5. Transition: Paris -> France
6. Transition: France -> World
7. Transition: World -> Germany
8. Transition: Germany -> Berlin
9. Transition: Berlin -> DDR Museum
10. Video: DDR Museum

11. Transition: DDR Museum -> Berlin
12. Transition: Berlin -> Germay
13. Transition: Germany -> Münster
14. Transition: Münster -> Domplatz
15. Video: Domplatz
16. Transition: Domplatz -> Münster
17. Transition: Münster -> IFGI
18. Video: IFGI
19. Transition: IFGI -> Münster
20. Transition: Münster -> Germany
21. Transition: Germany -> World

The current system doesn't allow the creation and management of tours, but it should be implemented to get the best experience. Still, the previous example is equally valid for tours and for manual travelling (the user selects where to go when he wants to go there, and not before starting the tour). The only thing the system needs to know is where you currently are and where to go to select the appropriate transitions and simulate the travel.

To get an even better experience of out IVE, we can correct the sudden change between transitions and videos. A simple way to solve it is to fade in the video when the transition finishes and fade out the video when the transition starts, or overlay the last frames of the ending video with the first frames of the next video, being one of the videos a travel transition and the other a video of a location.

One last enhancement of the system would be to find a way to include the compass in our transitions. GE doesn't allow us to change the location of the compass, and the upper right corner is not the best place to see it on our IVE because it would be out or on the edge of our field of view. An option would be to use overlays, but it would mean tedious long manual work and would have to be done for each transition individually.

7. Bibliography

7.1. Academic references

[A01] **Doug A. Bowman, David Koller and Larry F. Hodges** (1998) A methodology for the evaluation of travel techniques for Immersive Virtual Environments. *Virtual Reality*, Vol. 3, no. 2, pp. 120-131.

[A02] **Doug A. Bowman, Joseph L. Gabbard and Deborah Hix** (2002) A Survey of Usability Evaluation in Virtual Environments: Classification and Comparison of Methods. *Presence, Teleoperators and Virtual Environments*, Vol. 11, no. 4, pp. 404-424.

[A03] **Doug A. Bowman and Larry F. Hodges** (1999) Formalizing the design, evaluation, and application of interaction techniques for immersive virtual environments. *Journal of Visual Languages and Computing* Vol. 10, pp. 37-53.

[A04] **Doug A. Bowman, Donald B. Johnson and Larry F. Hodges** (1999) Testbed evaluation of virtual environment interaction techniques. *Proceedings of the ACM symposium on Virtual reality software and technology (VRST '99)*, pp. 26-33.

[A05] **Wayne D. Gray and Marilyn C. Salzman** (1998) Damaged Merchandise? A review of experiments that compare usability evaluation methods. *Human-Computer Interaction*, Vol. 13, pp. 203-261.

[A06] **Donald R. Lampton et al.** (1995) The Virtual Environment Performance Assessment Battery (VEPAB): Development and evaluation. *Presence: Teleoperators and Virtual Environments*, Vol. 3, pp. 145-157.

[A07] **Susan Bruck and Paul A. Watters** (2009) Estimating Cybersickness of Simulated Motion Using the Simulator Sickness Questionnaire (SSQ): A Controlled Study. *Sixth International Conference on Computer Graphics, Imaging and Visualization (CGIV'09)*, pp. 486-488.

[A08] **Jerrold D. Prothero** (1998) The Role of Rest Frames in Vection, Presence and Motion Sickness. *University of Washington*.

[A09] **Roy S. Kalawsky** (1999) VRUSE - A computerized diagnostic tool of virtual/synthetic environment systems. *Applied Ergonomics* Vol. 30, pp. 11-25.

[A10] **Doug A. Bowman, David Koller and Larry F. Hodges** (1997) Travel in Immersive Virtual Environments: An Evaluation of Viewpoint Motion Control Techniques. *Proceedings of the 1997 Virtual Reality Annual International Symposium (VRAIS '97)* pp. 45-52.

[A11] **Evan A. Suma et al.** (2010) Evaluation of the Cognitive Effects of Travel technique in complex real and virtual environments. *IEEE Transactions on visualization and computer graphics*, vol.16, no.4.

[A12] **Richard H. Y. So, W. T. Lo and Andy T. K. Ho** (2001) Effects of Navigation Speed on Motion Sickness Caused by an Immersive Virtual Environment. *Human Factors: The Journal of the Human Factors and Ergonomics Society* Vol. 43, pp. 452-461.

[A13] **Robert S. Kennedy et al.** (1993) Simulator Sickness Questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of aviation Psychology*, Vol. 3, pp. 203-220.

[A14] **David M. Johnson** (2007) Simulator Sickness Research Summary. *U.S. Army Research Institute for the Behavioral and Social Science, Fort Rucker Al*.

[A15] **Kay M. Stanney and Robert S. Kennedy** (1997) The Psychometrics of Cybersickness. *Communications of the ACM* Vol. 40 No.8, pp. 67-69.

[A16] **Sean D. Young, Bernard D. Adelstein and Stephen R. Ellis** (2006) Demand Characteristics of a Questionnaire Used to Assess Motion Sickness in a Virtual Environment. *Proceedings of the IEEE Virtual Conference (VR'06)*, pp. 97-102.

[A17] **Do Hoe Kim, Donald E. Parker and Min Young Park** (2004) A new procedure for measuring simulator sickness - The RSSQ. *University of Washington, Seattle, WA, USA*.

[A18] **J. A. Waterworth** (1999) Virtual Reality in medicine: A survey of the state of the art. *VRLab, Department of Informatics, Umeå University, Sweden*. (Online Nov. 2012) http://www8.informatik.umu.se/~jwworth/medpage.html

[A19] **Audrey Doyle** (1996) New report predicts high growth for VR. *Computer Graphics World* Vol. 19, Issue 9, p. 8.

[A20] **Samuel Greengard** (1998) 'Virtual' training becomes reality. *Industry Week* Vol. 247, p. 72.

[A21] **Mary Hegarty, Anthony E. Richardson, Daniel R. Montello, Kristin Lovelace and Ilavanil Subbiah** (2002) Development of a self-report measure of environmental spatial ability. *Intelligence* Vol. 30, pp. 425-447.

[A22] **Sandra G. Hart and Lowell E. Staveland** (1988) Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. *Human mental workload*, Vol. 1, pp. 139-183.

[A23] **Sandra G. Hart** (2006) NASA-task load index (NASA-TLX): 20 years later. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. SAGE Publications, pp. 904-908.

[A24] **Dustin B. Chertoff, Brian Goldiez and Joseph J. Laviola** (2010) Virtual Experience Test: A virtual environment evaluation questionnaire. *Virtual Reality Conference (VR), 2010 IEEE*. IEEE, pp. 103-110.

[A25] **Ralph Schroeder** (2008) "Virtual Worlds Research: Past, Present and Future", Defining Virtual Worlds and Virtual Environments. *Journal of Virtual Worlds Research*, Vol. 1, no. 1.

[A26] **William Bricken** (1990) Virtual reality: Directions of growth. *Notes from the SIGGRAPH*, Vol. 90, pp. 90-91.

[A27] **Arun Katkere, Saied Moezzi, Don Y Kuramura, Patrick Kelly and Ramesh Jain** (1997) Towards video-based immersive environments. *Multimedia Systems*, Vol. 5, no. 2, pp. 69-85.

[A28] **Ulrich Neumann, Thomas Pintaric and Albert Rizzo** (2000) Immersive panoramic video. *International Multimedia Conference: Proceedings of the eighth ACM international conference on Multimedia*, pp. 493-494.

[A29] **Doug A. Bowman et al.** (1999) Maintaining spatial orientation during travel in an immersive virtual environment. *Presence*, Vol. 8, no. 6, pp. 618-631.

[A30] **Doug A. Bowman et al.** (1999) The educational value of an information-rich virtual environment. *Presence: Teleoperators & Virtual Environments*, Vol. 8, no. 3, pp. 317-331.

[A31] **Doug A. Bowman** (1998) Interaction techniques for immersive virtual environments: Design, evaluation, and application. *Human-Computer Interaction Consortium Conference*, Vol. 98.

[A32] **Douglas A. Bowman** (1999) Interaction techniques for common tasks in immersive virtual environments. *Doctoral dissertation, Georgia Institute of Technology*.

[A33] **Jürgen P. Schulze, Andrew S. Forsberg and Mel Slater** (2005) Analysis of subject behavior in a virtual reality user study. *Presence*, pp. 255-260.

[A34] **Julie Marie Drexler** (2006) Identification of system design features that affect sickness in virtual environments. *Doctoral dissertation, University of Central Florida Orlando, Florida*.

[A35] **Paulo Dias et al.** (2007) Usability in virtual and augmented environments: a qualitative and quantitative study. *Electronic Imaging Conf., SPIE Vol. 6490, Stereoscopic Displays and VR Systems XIV*, p. 64901I.

[A36] **Beatriz Sousa Santos et al.** (2009) Usability evaluation in Virtual Environments through empirical studies involving users. *Challenges in the Evaluation of Usability and User Experience in Reality Based Interaction*, p. 28.

[A37] **Kay M. Stanney et al.** (2003) What to expect from immersive virtual environment exposure: Influences of gender, body mass index, and past experience. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Vol. 45, no. 3, pp. 504-520.

[A38] **Randy Pausch, Dennis Proffitt and George Williams** (1997) Quantifying immersion in virtual reality. *Proceedings of the 24th annual conference on Computer graphics and interactive techniques. ACM Press/Addison-Wesley Publishing Co.*, pp. 13-18.

[A39] **Eugenia M. Kolasinski** (1996) Prediction of simulator sickness in a virtual environment. *Doctoral dissertation, University of Central Florida Orlando, Florida.*

[A40] **Fernando A. Das Neves and Edward A. Fox** (2000) A study of user behavior in an immersive virtual environment for digital libraries. *Proceedings of the fifth ACM conference on Digital libraries, ACM*, pp. 103-111.

7.2. Technical references

[T01] **VLC Media Player**. Video Lan Organization. (Last accessed Online Oct. 2012) http://www.videolan.org/vlc/

[T02] **Java**. Oracle. (Last accessed Online Oct. 2012) http://www.java.com/

[T03] **Grails**. Grails. (Last accessed Online Sep. 2012) http://grails.org

[T04] **Android**. Android. Google. (Last accessed Online Sep. 2012) http://www.andorid.com

[T05] **Google Maps API**. Google Developers. Google. (Last accessed Online Oct. 2012) https://developers.google.com/maps/

[T06] **OpenStreetMaps API**. OpenStreetMap.org (Last accessed Online Nov. 2012) http://wiki.openstreetmap.org/wiki/API_v0.6

[T07] **Google Street View API**. Google Developers. (Last accessed Online Oct. 2012) https://developers.google.com/maps/documentation/javascript/streetview

[T08] **Panoramio API**. Panoramio. (Last accessed Online Oct. 2012) http://www.panoramio.com/api/widget/api.html

[T09] **Flickr API**. Flickr. Yahoo. (Last accessed Online Nov. 2012) http://www.flickr.com/services/api/

[T10] **Google Earth API**. Google Developers. Google. (Last accessed Online Nov. 2012) https://developers.google.com/earth/

[T11] **AnyVideoConverter**. Any Video Converter freeware. Anvsoft Inc. (Last accessed Online Dec. 2012) http://www.any-video-converter.com/products/for_video_free/

[T12] **VirtualDub**. VirtualDub.org. (Last accessed Online Dec. 2012) http://www.virtualdub.org/

[T13] **Google Drive**. Google. (Last accessed Online Jan. 2013) https://www.google.com/intl/es/drive/start/index.html

[T14] **Bing Maps API**. Microsoft. (Last accessed Online Jan. 2013) http://www.microsoft.com/maps/isdk/ajax

[T15] **Yahoo Maps API**. Yahoo!. (Last accessed Online Jan. 2013) http://developer.yahoo.com/maps

[T16] **OssimPlanet**. OSGeo.org. (Last accessed Online Oct. 2012) http://trac.osgeo.org/ossim/

[T17] **NASA World Wind**. NASA. (Last accessed Online Oct. 2012) http://worldwind.arc.nasa.gov/features.html

[T18] **NASA-TLX**. NASA. (Last accessed Online Oct. 2012) http://humansystems.arc.nasa.gov/groups/TLX/

7.3. Other references

[O01] **Immersive Technologies.** Advanced equipment simulators for mining and earthmoving equipment training. (Online Oct. 2012) http://www.immersivetechnologies.com/

[O02] **ImTech.** Immersive Technologies. (Online Nov. 2012) http://www.immersivetech.org/category/academic

[O03] **John P. Mello Jr.** Microsoft patent reveals immersive gaming environment. *PC World*. (Online Sep. 2012) http://www.pcworld.com/article/262143/microsoft_patent_reveals_immersive_gaming_environment.html

[O04] **Sitcom Lab**. IFGI, WWU. (Last accessed Online Feb. 2013) http://sitcom.uni-muenster.de

[O05] **earthmine**. Earthmine Inc.. (Last accessed Online Feb. 2013) http://www.earthmine.com/index

[O06] **MapJack**. MapJack. (Last accessed Online Feb. 2013) http://www.mapjack.com/

[O07] **CycloMedia**. Cyclomedia. (Last accessed Online Feb. 2013) http://www.mapjack.com/

[O08] **Driveme.in**. Driveme.in. (Last accessed Online Feb. 2013) www.driveme.in/

[O09] **VideoStreetView**. GlobalVision Communication. (Last accessed Online Feb. 2013) http://web.archive.org/web/20130203141239/http://www.videostreetview.com/

[O10] **Internet Archive WayBack Machine**. Internet Archive (Last accessed Online Feb. 2013) http://archive.org/web/web.php

[O11] **Audrey Doyle** (1996) New report predicts high growth for VR. *Computer Graphics World*, Vol. 19, no. 9, pp. 8

[O12] **Sharp Provides Large Multi-Screen Display System to Huis Ten Bosch Theme Park in Nagasaki, Japan** (2011) Sharp press releases. (Last accessed Online Oct. 2012) http://www.sharp-world.com/corporate/news/110426.html

[O13] **Cheryl Pellerin** (2011) Immersive Technology Fuels Infantry Simulators. *American Forces Press Service*. (Last accesed Online Dec. 2012) http://www.defense.gov/News/NewsArticle.aspx?ID=63933

[O14] **Chang Ha Lee et al.** (2006) Towards an immersive virtual environment for medical team training. *Studies in health technology and informatics*, Vol. 125, p. 274.

[O15] **State-of-the-art virtual-reality system is key to medical discovery**. KurzweilAI. (Last accessed Online Jan. 2013) http://www.kurzweilai.net/state-of-the-art-virtual-reality-system-is-key-to-medical-discovery

[O16] **Leonidas Deligiannidis and Robert J. Jacob** (2008) An Immersive Environment for the Vase Museum.

8. Annexes

8.1. SSQ

8.1.1. URLs

Next you can find the URLs to the online forms created specifically for this research study using the Google Drive Forms technology.

8.1.1.1. Pre-SSQ URL

https://docs.google.com/a/uji.es/spreadsheet/viewform?formkey=dFZWSW1VMWVRWjNnei0yaWpkWkZZelE6MQ

8.1.1.2. Post-SSQ URL

https://docs.google.com/a/uji.es/spreadsheet/viewform?formkey=dDh3VzRocDh0YjFQNXdxMXcyOGFaVnc6MQ

8.1.2. Printable versions

These are the printing versions of the SSQ forms. We haven't used them, but the online versions were used instead.

8.1.2.1. Pre-SSQ printable version

Pre-exposure Simulator Sickness Questionnaire

Pre-exposure instructions: please fill in this questionnaire. Circle below if any of the symptoms apply to you now. You will be asked to fill this again after the experiment.

Name:

01. General discomfort	None	Slight	Moderate	Severe
02. Fatigue	None	Slight	Moderate	Severe
03. Headache	None	Slight	Moderate	Severe
04. Eyestrain	None	Slight	Moderate	Severe
05. Difficulty focusing	None	Slight	Moderate	Severe
06. Salivation increase	None	Slight	Moderate	Severe
07. Sweating	None	Slight	Moderate	Severe
08. Nausea	None	Slight	Moderate	Severe
09. Difficulty concentrating	None	Slight	Moderate	Severe
10. "Fullness of the head"	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness eyes open	None	Slight	Moderate	Severe
13. Dizziness eyes close	None	Slight	Moderate	Severe
14. Vertigo	None	Slight	Moderate	Severe
15. Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

8.1.2.2. Post-SSQ printable version

Post-exposure Simulator Sickness Questionnaire

Post-exposure instruction: please fill in this questionnaire once more. Circle below if any of the symptoms apply to you now.

Name:

01. General discomfort	None	Slight	Moderate	Severe
02. Fatigue	None	Slight	Moderate	Severe
03. Headache	None	Slight	Moderate	Severe
04. Eyestrain	None	Slight	Moderate	Severe
05. Difficulty focusing	None	Slight	Moderate	Severe
06. Salivation increase	None	Slight	Moderate	Severe
07. Sweating	None	Slight	Moderate	Severe
08. Nausea	None	Slight	Moderate	Severe
09. Difficulty concentrating	None	Slight	Moderate	Severe
10. "Fullness of the head"	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness eyes open	None	Slight	Moderate	Severe
13. Dizziness eyes close	None	Slight	Moderate	Severe
14. Vertigo	None	Slight	Moderate	Severe
15. Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

8.1.3.Test results

8.1.3.1. Pre-SSQ test results

Q#	Symptom	user 02	user 03	user 04	user 01	user 08	user 05	user 09	user 07	user 06	user 10
1	General discomfort	0	0	0	0	1	0	0	1	0	0
2	Fatigue	0	1	0	0	2	0	0	2	1	0
3	Headache	1	0	0	0	0	0	0	2	1	1
4	Eyestrain	0	0	0	0	1	1	1	0	1	0
5	Difficulty focusing	0	1	0	0	0	1	0	1	0	0
6	Salivation increase	0	0	0	0	0	0	0	0	0	0
7	Sweating	1	0	0	0	0	0	0	0	0	0
8	Nausea	0	0	0	0	0	0	0	0	0	0
9	Difficulty concentrating	0	2	0	0	1	0	0	0	1	0
10	"Fullness of the head"	0	0	0	0	2	0	0	1	1	0
11	Blurred vision	0	1	0	0	0	0	0	0	1	0
12	Dizziness eyes open	0	0	1	0	0	0	0	0	0	0
13	Dizziness eyes closed	0	0	0	0	0	0	0	0	0	0
14	Vertigo	0	0	0	0	0	0	0	0	0	0
15	Stomach awareness	0	0	0	0	0	0	0	0	0	0
16	Burping	0	0	0	0	0	0	0	0	0	0

8.1.3.2. *Post-SSQ test results*

Q#	Symptom	user 01	user 02	user 03	user 04	user 05	user 06	user 07	user 09	user 08	user 10
1	General discomfort	0	0	1	0	1	2	1	0	1	0
2	Fatigue	0	1	1	0	1	1	0	0	1	1
3	Headache	0	1	0	0	1	2	2	0	0	0
4	Eyestrain	2	1	1	0	1	2	1	1	0	0
5	Difficulty focusing	0	1	1	0	1	1	1	0	0	0
6	Salivation increase	0	0	0	0	0	0	0	0	0	0
7	Sweating	0	1	0	0	0	0	0	0	0	0
8	Nausea	0	0	0	0	0	1	0	0	0	0
9	Difficulty concentrating	0	0	2	0	0	1	0	0	1	1
10	"Fullness of the head"	1	0	0	0	1	1	1	0	1	0
11	Blurred vision	0	1	1	0	0	0	0	0	1	0
12	Dizziness eyes open	0	0	1	0	1	1	0	0	0	0
13	Dizziness eyes closed	0	0	0	0	1	1	1	1	0	0
14	Vertigo	0	0	0	0	0	0	0	0	0	0
15	Stomach awareness	0	0	0	0	0	0	0	0	0	0
16	Burping	0	0	0	0	0	0	0	0	0	0

8.2. VRUSE

8.2.1. URL

https://docs.google.com/a/uji.es/spreadsheet/viewform?formkey=dEZMeHEzNW4yaTZEQVB5YXdVSV92eWc6MQ

8.2.2. Printable version

VRUSE Questionnaire

Instructions: please, fill in this questionnaire. Circle below your opinion in each of the following statements about the system you have just experienced.

Name:

SECTION I: System Output (Display)

01. I found the display device appropriate for the task

completely disagree disagree no opinion agree completely agree

02. The amount of lag (delays) in the image affected my performance

completely disagree disagree no opinion agree completely agree

03. The display resolution was adequate for the task

completely disagree disagree no opinion agree completely agree

04. I was aware of distortions in the image

completely disagree disagree no opinion agree completely agree

05. The display field of view was appropriate for the task

completely disagree disagree no opinion agree completely agree

06. The quality of the image affected my performance

completely disagree disagree no opinion agree completely agree

07. Information was presented in a meaningful way

completely disagree disagree no opinion agree completely agree

08. There were no glitches in the display

completely disagree disagree no opinion agree completely agree

09. Display feedback was adequate for the task

completely disagree disagree no opinion agree completely agree

10. My eyes felt uncomfortable after using the system

completely disagree disagree no opinion agree completely agree

11. Objects in the virtual environment were very realistic

completely disagree disagree no opinion agree completely agree

12. I had difficulty getting used to the display

completely disagree disagree no opinion agree completely agree

13. Displayed information was too complicated

completely disagree disagree no opinion agree completely agree

14. I felt nauseous when using the system

completely disagree disagree no opinion agree completely agree

15. I lacked a sense of depth in the image

completely disagree disagree no opinion agree completely agree

16. Overall I would rate the display system as:

very satisfactory, satisfactory, neutral, unsatisfactory or very unsatisfactory.

SECTION II: Information Consistency

17. The information presented by the system was consistent

completely disagree disagree no opinion agree completely agree

18. Overall I would rate the consistency of the system as:

very satisfactory, satisfactory, neutral, unsatisfactory or very unsatisfactory.

SECTION III: Simulation Fidelity

19. The underlying simulation was accurate

completely disagree disagree no opinion agree completely agree

20. The simulation was too simplistic to be of use

completely disagree disagree no opinion agree completely agree

21. The simulation behaved in a very unusual manner

completely disagree disagree no opinion agree completely agree

22. Objects in the virtual environment moved in a natural manner

completely disagree disagree no opinion agree completely agree

23. I felt disorientated in the virtual environment

completely disagree disagree no opinion agree completely agree

24. I had the right level of control over the simulation

completely disagree disagree no opinion agree completely agree

25. The virtual environment was too complicated

completely disagree disagree no opinion agree completely agree

26. The simulation appeared to freeze or pause at intervals

completely disagree disagree no opinion agree completely agree

27. Overall I would rate the fidelity of the simulation as:

very satisfactory, satisfactory, neutral, unsatisfactory or very unsatisfactory.

SECTION IV: Sense of Immersion (Presence)

28. I felt a sense of being immersed in the virtual environment

completely disagree disagree no opinion agree completely agree

29. I got a sense of presence (i.e. being there)

completely disagree disagree no opinion agree completely agree

30. The quality of the image reduced my feeling of presence

completely disagree disagree no opinion agree completely agree

31. I thought that the field of view enhanced my sense of presence

completely disagree disagree no opinion agree completely agree

32. The display resolution reduced my sense of immersion

completely disagree disagree no opinion agree completely agree

33. I felt isolated and not part of the virtual environment

completely disagree disagree no opinion agree completely agree

34. I had a good sense of scale in the virtual environment

completely disagree disagree no opinion agree completely agree

35. I often did not know where I was in the virtual environment

completely disagree disagree no opinion agree completely agree

36. Overall I would rate my sense of presence as:

very satisfactory, satisfactory, neutral, unsatisfactory or very unsatisfactory.

8.2.3.Test results

Q#	Question	user 01	user 02	user 03	user 04	user 05	user 06	user 07	user 08	user 09	user 10
1	I found the display device appropriate for the task	4	5	3	5	4	2	4	4	4	4
2	The amount of lag (delays) in the image affected my performance	4	2	2	5	3	3	3	3	3	3
3	The display resolution was adequate for the task	4	4	5	5	4	2	5	5	5	4
4	I was aware of distortions in the image	3	2	3	5	3	2	1	2	2	3
5	The display field of view was appropriate for the task	3	4	4	5	4	2	4	3	4	3
6	The quality of the image affected my performance	4	4	4	5	4	3	4	2	4	3
7	Information was presented in a meaningful way	3	4	4	5	3	4	4	4	4	3
8	There were no glitches in the display	5	5	5	5	4	3	4	4	5	3
9	Display feedback was adequate for the task	4	4	4	5	3	4	4	4	4	3
10	My eyes felt uncomfortable after using the system	4	3	2	5	4	2	4	4	2	4
11	Objects in the virtual environment were very realistic	3	3	5	4	3	4	3	5	4	3
12	I had difficulty getting used to the display	5	4	2	5	4	4	4	4	5	3
13	Displayed information was too complicated	5	5	4	5	4	5	4	3	5	3
14	I felt nauseous when using the system	5	5	5	5	4	2	5	5	5	5
15	I lacked a sense of depth in the image	3	5	3	5	4	4	5	3	4	5
16	Overall I would rate the display system as	**3**	**2**	**4**	**5**	**3**	**4**	**2**	**4**	**4**	**2**
17	The information presented by the system was consistent	4	4	4	5	3	4	4	4	4	3
18	Overall I would rate the consistency of the system as:	**2**	**2**	**3**	**5**	**3**	**4**	**2**	**4**	**4**	**2**
19	The underlying simulation was accurate	3	4	4	5	4	4	3	4	4	3

20	The simulation was too simplistic to be of use	4	4	2	4	2	2	2	4	3	3
21	The simulation behaved in a very unusual manner	5	5	3	5	2	4	3	4	4	4
22	Objects in the virtual environment moved in a natural manner	4	3	4	5	3	1	4	2	3	3
23	I felt disorientated in the virtual environment	5	4	2	5	4	2	4	3	5	4
24	I had the right level of control over the simulation	3	2	1	4	3	4	4	4	5	3
25	The virtual environment was too complicated	5	5	5	4	4	5	5	4	5	5
26	The simulation appeared to freeze or pause at intervals	5	4	3	5	3	5	2	5	4	3
27	Overall I would rate the fidelity of the simulation as:	**4**	**4**	**4**	**5**	**3**	**4**	**2**	**5**	**4**	**2**
28	I felt a sense of being immersed in the virtual environment	4	3	4	4	4	4	4	2	3	3
29	I got a sense of presence (i.e. being there)	4	3	4	5	4	4	3	4	3	3
30	The quality of the image reduced my feeling of presence	4	3	3	5	3	5	4	3	5	4
31	I thought that the field of view enhanced my sense of presence	4	3	4	4	3	4	3	4	3	3
32	The display resolution reduced my sense of immersion	5	3	5	4	3	5	4	2	5	4
33	I felt isolated and not part of the virtual environment	5	2	3	5	4	5	4	5	4	5
34	I had a good sense of scale in the virtual environment	4	3	5	1	3	5	3	4	4	3
35	I often did not know where I was in the virtual environment	1	3	5	2	4	5	2	4	4	4
36	Overall I would rate my sense of presence as:	**2**	**3**	**4**	**5**	**4**	**4**	**2**	**5**	**3**	**3**

8.3. Locations

8.3.1. URLs

These are the URLs to the 40 seconds sample videos of the locations. The videos used in the tour are the 90 seconds version.

- Location 1: http://youtu.be/bf0rFYW77xc
- Location 2: http://youtu.be/PxTQMLtxrtI
- Location 3: http://youtu.be/BhWvX8hft7g
- Location 4: http://youtu.be/fvjJI59ugkg
- Location 5: http://youtu.be/-hmm9ZLjdxY
- Location 6: http://youtu.be/w5bZGqHrRBo
- Location 7: http://youtu.be/4hltIHJPLnM
- Location 8: http://youtu.be/rhU3mTerS8U
- Location 9: http://youtu.be/QhfAJTpRLiU

8.3.2. KML

Due to the huge size of the code, and the inefficiency of directly including the code here, we can access and/or download the KML file directly using the following URLs:

- Access (the locations will be displayed in a map): https://docs.google.com/file/d/0Bw1I4ISRGLRvandZY1FfZFVHTlU/edit

- Download: https://docs.google.com/uc?export=download&id=0Bw1I4ISRGLRvandZY1FfZFVHTlU

8.4. Travel transitions

8.4.1. URLs

- Transition 1: http://youtu.be/YX1JUD_nfVQ
- Transition 2: http://youtu.be/0zxEpTh_bmg
- Transition 3: http://youtu.be/P9IrVdhRTPI
- Transition 4: http://youtu.be/tPte7_TnzXs
- Transition 5: http://youtu.be/tajWoVPcdYM
- Transition 6: http://youtu.be/t8HsEgMryMA
- Transition 7: http://youtu.be/Mxk9peHNlnU
- Transition 8: http://youtu.be/dmxeiILU_mI
- Transition 9: http://youtu.be/WQ-LQ8-E_jo
- Transition 10: http://youtu.be/cpllpISxOc0

8.4.2. KML

Due to the huge size of the code, and the inefficiency of directly including the code here, we can access and/or download the KML file directly using the following URLs:

- Access (the tours of the transitions will be displayed in a map): https://docs.google.com/file/d/0Bw1I4ISRGLRvMF94aFRkMUlLdUU/edit

- Download: https://docs.google.com/uc?export=download&id=0Bw1I4ISRGLRvekdMQnlvUTBma28

8.5. Tour

- URL of the tour video: http://youtu.be/VBnQAZBXVI8