UNIVERSITY OF OSLO
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Holmenkollen Time Travel

Developing a Situated Simulation for a handheld device

Master thesis
60 credits

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Abstract

Holmenkollen is a ski jumping hill, a place and a structure of cultural and historical importance in Norway. This thesis describes the development of the situated simulation Holmenkollen Time Travel (HTT), an application made for iPad2. The HTT allows a user to “travel in time” to experience four different versions of the ski jumping hill, hence the name. The application is tested on location by different user groups and the feedback from the individuals shows how the HTT can enhance a user’s experience of Holmenkollen. The application introduces some new developments to the concept of situated simulations, and is further analyzed within the theoretical framework of Augmented Reality and Place Specific Computing.

Acknowledgements

I would really like to thank my supervisor Gunnar Liestøl for his excellent support during the whole process; it's been a pleasure working with you. I would also like to thank those affiliated with the INVENTIO-Project who has given me a hand, and a special thanks to Tomas Stenarson who has been a really helpful during the development phase.

Thanks to my informants, especially to Klaus Kromann in the Ski Federation. You have been a great asset to me.

Mikkel, my good friend and colleague, you have been great support. You have given me lots of valuable input and motivation when I needed it the most. Thank you for being there!

What would the days have been like without good friends and lunch-buddies? Jenny and Ann Kristin, thanks for all the laughs. I will miss working next to you! A big thanks to the rest of my friends from the media department, I'm going to miss the Quiz-breaks.

Last but not least, to the two women in my life!

Thanks mom for cleaning up my grammatical mistakes, and for caring about my wellbeing. (You probably should have proofed this part as well…)

Siv Helén, thank you for putting up with all my crap, for helping me structure my thesis, for making me dinner and turning the light back on every time it got dark. I love you! You're the Best!

“Ett heligt berg...”

Liksom Olympen i Grekland i sig innefattade icke blott berget med samma namn, utan hela gudomen, så får vi i våra dagar använda samma måttstock på Holmenkollen i Norge.

Det är namnet på nationalsporten, nationalbacken, nationaldagen. Det är ett heligt berg.

Den svenske avisen
Svenska Dagbladet
Stockholm 1920

“A holy mountain...”

Like Mount Olympus in Greece, the name means more than the hill itself, it describes the divine. That is also how we see Holmenkollen, Norway.

It is the name of the national sport, the national hill, the national day. It is a holy mountain.

Den svenske avisen
Svenska Dagbladet
Stockholm 1920

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1 Introduction

1.1 Research Question

My aim with this thesis is to make an iPad application, a location-aware application that introduces new functionalities to the concept of Situated Simulation.

The application is tested by different user groups using ethnographic methodology in order to explore how the application, both in the form of the existing prototype, potentially through an eventual commercialized application or similar applications, can contribute in enhancing users' experience of a specific place.

I have used theoretical perspectives of Augmented Reality and Place Specific Computing when analyzing the development of the application and its' use in order to give context to the application and the design approach.

1.2 Background

The rapid technological development of handheld devices has brought us far. When it comes to processing power and hardware features, the products you carry in your pocket can nearly compete with the computers we use at home or in the office. In addition they have adopted locative functionality found in GPS devices and have rich camera features. These products create new possibilities, giving us new possible genres and new ways of presenting material both visually and through new functionality.

I have created an application for ipad2, *Holmenkollen Time Travel (HTT)* that uses the inherent features of the device to recreate lost architectural structures on location. The application is based on the *situated simulations (sitsim)* first introduced by Liestøl in the INVENTIO-project. These situated simulations are built in 3D, and require the handheld unit to handle high level graphics. They use location and orientation capabilities in the device, (GPS, digital compass, accelerometer and gyroscope) to transfer movement from the real world into the application and use it as navigation. In a *sitsim* there is coherence between the users' visual perspective on screen and perspective of the real physical environment surrounding the user. The Situated Simulation creates a representation of a space, phenomenon or a structure that is invisible to the eye or has ceased to exist.

Holmenkollen is a ski jumping hill in Oslo, Norway situated north-west of the city center. No single arena has had a bigger influence on the sport of ski jumping. No ski arena has stronger traditions or has gathered more spectators. “We’re usually quite modest when we say that New York has the Statue of Liberty, Paris has the Eiffel Tower and we have Holmenkollen”, says the Deputy Secretary General of the Norwegian Ski Association.

The *HTT* is my attempt to add new features to the earlier Situated Simulations: the feature of experiencing change over time has been used in both Temple of JC and in the last version of Parthenon, but has a much stronger focus within HTT. The *HTT* allows the user to “travel in time”, seeing the major developments from the original hill (build in 1892) to the present hill build in 2010. The three earlier versions of the ski jumping hill that is modeled in 3D have equal importance in the application and encourage the user to explore the different times. These Virtual Environments also include information on significant developments in ski jumping. The application represents an alternative way of viewing the scale and architecture of Holmenkollen. It also includes ski jumping material which is essential to the location. This proof of concept prototype shows 3 major reconstructions of Holmenkollen over the last 119 years. The application provides a unique perspective on Holmenkollen as the user can explore the hills from 1892, 1952 and 1982 on location. These hills are recreated in 3D, and the present day hill is presented through a camera-view of the iPad. HTT is an opportunity to re-live different times in a historical landmark. The 3D terrain surrounding the arena is filled with links to information about Holmenkollen, ski jumping, history and objects, presented through video, illustrations, pictures and sound. The links are there for the user to gain more knowledge and to enhance the experience. HTT also introduce a wider use of web controlled content and videos in sitsim than used before.

The prototype has been tested by different user groups, including media students, ordinary tourists and key persons involved in the management of the ski arena. My aim is to find out what this type of application can add to the experience of architectural structures and development, possibly enhancing the overall experience of a place or a building at the same time as it increases one’s historical knowledge. Holmenkollen has the ski museum just underneath the tower of the ski jumping hill. Hopefully HTT can be part of supplementing the information visitors get inside the museum with a highly location and context based information in the arena.

1.3 Motivation

As I have been a part of developing the “Forum Iulium”, a Situated Simulation application in Rome, Italy made by the INVENTIO-project the spring of 2010 (Orkelbog, 2010) (Liestøl, 2011b), I had both experience and a desire to work more with this concept. Holmenkollen was at that time center of attention as a new ski jumping hill just had been built and the FIS Nordic ski world championships were just around the corner. This arena became the perfect object for me to develop a new and somewhat different situated simulation application.

1.4 Holmenkollen History

In 2007 Holmenkollen was the most visited tourist attraction in Norway with 643 620 visitors. (VG.no, 2008) Before 1892 the ski jumping competitions were held in Huseby but were hampered by the lack of snow. During the winter of 1891 Hans Krag and Fritz Huitfeldt went on a mission to Holmenkollåsen to find a place for a new ski jumping hill on a higher altitude, with better snow conditions. By the time they reached Besserudmyra they had yet to find a suitable slope for ski jumping. Suddenly Huitfeldt stopped, looked up and said: “This is where the jump hill should be!” In the winter of 1892 the first Holmenkollen ski jumping competition was organized and it was a great success. More than 12000 people came to Holmenkollen to see the first hill record. (Hedenstad et al., 2010 p. 70)

In 1892 Holmenkollen was merely a construction of snow and branches but through the years Holmenkollbakken developed and increased in size. The ski jump has been re-developed on no less than 18 occasions and is now the world’s most modern ski jumping hill.(Holmenkollen.com, 2011) Holmenkollen was already improved in its second year, and by 1914 the first tower was erected. The tower was referred to as “the tower of Babel” as it rose 9,5 meters above the ground.(Holmenkollen.com, 2011) In 1927, the day after a competition, the tower collapsed due to heavy snowfall, and a new, bigger and improved tower was built, 9 meters further back into hill and 10 meters higher. By 1929 the first 50 meter jump was made in Holmenkollen. Holmenkollen anno 1952 was originally planned and construction begun as a venue for the World Championships in 1940. World War II got in the way of put a stop to those plans, but construction started up again right after the war. New stands and a new hill profile were developed, but when Holmenkollen was awarded the Olympics 1952 the hill was further modified. It was completed just ahead of the Olympics in Oslo and said to be an architectural masterpiece, built of concrete and wood, and the first ski jumping hill with permanent stands built alongside the landing area. The ski museum was moved from Frognerseteren and into the building underneath the jump and a grandstand for the royal family added. The cost of building the new Holmenkollen arena was huge and was paid by Oslo municipality. A new spectator record was set on the day of the Olympic competition when 120000 people witnessed Arnfinn Bergmann taking the gold medal for Norway.

The hill was further expanded before the world championships in 1966. In 1982 the inrun was made taller and longer, a mobile start platform was installed, and an electronic measuring system taken into use. The knoll and landing slope were adjusted, and in the transition to the out-run, 130,000 cubic meters of mass was blasted away, and Besserudkjernet’s depth was increased by 7 meters. This made way for longer jumps and permitted additional grandstands to be built and the last wooden grandstands were removed. Throughout the 90’s Holmenkollbakken was further modified. The inrun got porcelain tracks and new flood lighting was installed. No major changes were made to the concrete construction. From the year 2000 the discussion of building a new Holmenkollen started. Three options where weighed: some suggested they could modify the hill, others suggested to tear the whole thing down and build a new jump hill, while some suggested moving Holmenkollbakken to Rødkleiva. (Hedenstad et al., 2010 p.80) On 22 September 2005, FIS (the international ski federation) intervened the progress of the decision by stating that an all-new Holmenkollbakken would have to be built if Oslo was to host future World Championships and World Cup tournaments. The municipality issued an architectural design competition to rebuild the hill and Julien De Smedt's proposal was selected among 104 entrants.

The new Holmenkollen was completed in 2010 and the hill’s first competition, the Continental Cup, was held early March that same year. Holmenkollen has a hill size of HS134, a construction point of K-120, and a capacity for 30,000 spectators. The arena is prepared for the athletes and the public with a cabin lift with glass windows that go all the way to the top. Like most of the former arenas in Holmenkollen it has a grandstand for the royal family, state of the art judges’ booths and upgraded light and sound facilities. In addition, it has permanent wind protection as an integral part of the inrun structure.(Holmenkollen.com, 2011)

1.5 Situated Simulation

Situated simulation (sitsim) is an application developed by the INVENTIO-Project (Liestøl, 2009) that requires a smartphone or a handheld computer. The handheld computer needs to have location and orientation capabilities available through hardware like GPS, compass, accelerometer and gyroscope. In addition it needs a high resolution screen, a good graphics engine, a powerful processor and 3G/wireless networking. Only three to four years back in time, this would have sounded extremely expensive and difficult to get hold of, but in today's tablet and smartphone market it is quite ordinary. *Sitsim* applications have up to now been made for iPhone and iPad, but will also be available for Android. The application exhibits a multimodal 3D environment in which the user can move around and interact with the applications interface. *"The handheld computer serves as a point of view – a virtual camera – which provides a continually changing perspective into the graphics environment"*. (Liestøl, 2011a p. 310) The movement inside the application is controlled by the users own movements and the location and orientation technology within the device. As the user walks, turns around and tilts the device in all directions the view of the real world and virtual world changes simultaneously. In other words the real world which the user is moving in and the virtual presentation align and create an alternative view on the case studied. The 3D graphics is a window to or a representation of, a space, a topic, phenomenon or structure that is no longer there, hidden in some way or something that does not exist. The perspective can represent something present, from the past or something that lies in the future.

1.6 Holmenkollen as Situated Simulation

In the case of HTT the *sitsim* is based on the ski jumping hill situated at Holmenkollåsen in Oslo, Norway. The motivation behind implementing a Holmenkollen *sitsim* was to visualize the history of Holmenkollen and the evolution of the sport itself. Since the size and the curves of the ski jumping hill has a large effect on how a ski jumper performs, Holmenkollen has seen many and big changes throughout the last century as the sport has evolved accordingly. These reconstructions and modifications can be seen at the Holmenkollen ski museum. There are physical 3D models of the major reconstructions as well as videos and pictures. As you go further back in time less material will be available and it becomes harder to visualize the hill and the size of it. By building 3D models of three selected hills from important moments in the Holmenkollen history, I will provide a new and different way to experience the famous sports arena. *Holmenkollen Time Travel* gives an opportunity to be physically present in the hill, while at the same time travelling back in time to 1892, 1952 and 1982 to see the architectural changes. At the same time it will be possible to learn more about ski jumping, the equipment, the technique and other important facts that are a part of Holmenkollen history.

1.7 iPad and iOS

Earlier *sitsim* has been made for the iPhone exclusively. In later versions like the one found in the Apple app store “Borrehallen” has also been optimized for iPad 2. IPad 2 has of today a stronger processor, graphics engine and a larger screen to make the experience better and more detailed. The magnetometer and Gyroscope gives both direction awareness and direction stability. One can always argue that iPhone apps are more accessible to a larger crowd and that the iPhone is far easier to bring along and is owned by a larger group of consumers. Since HTT is a proof of concept application, usability has been the most important factor in the search for good test results.

iOS is Apple’s proprietary mobile platform. It was originally designed for the iPhone when it was first launched but has later been integrated in devices like the iPod touch, iPad and Apple TV. iOS has by October 2011 been released in build 5.0 also called iOS 5, for all devices. The HTT application has been tested on both the iOS 4 and iOS 5 during the user tests. Apple Inc.’s App Store is a database for third party applications for the iOS. Apple revolutionized the app industry with the App Store, which now has more than 500,000 apps and where customers have downloaded more than 18 billion apps. (Wauters, 2011)

iPad 2 specifications:

Location

- Wi-Fi
- Digital compass
- Assisted GPS
- Cellular

Chip

- 1GHz dual-core Apple A5 custom-designed, high-performance, low-power system-on-a-chip

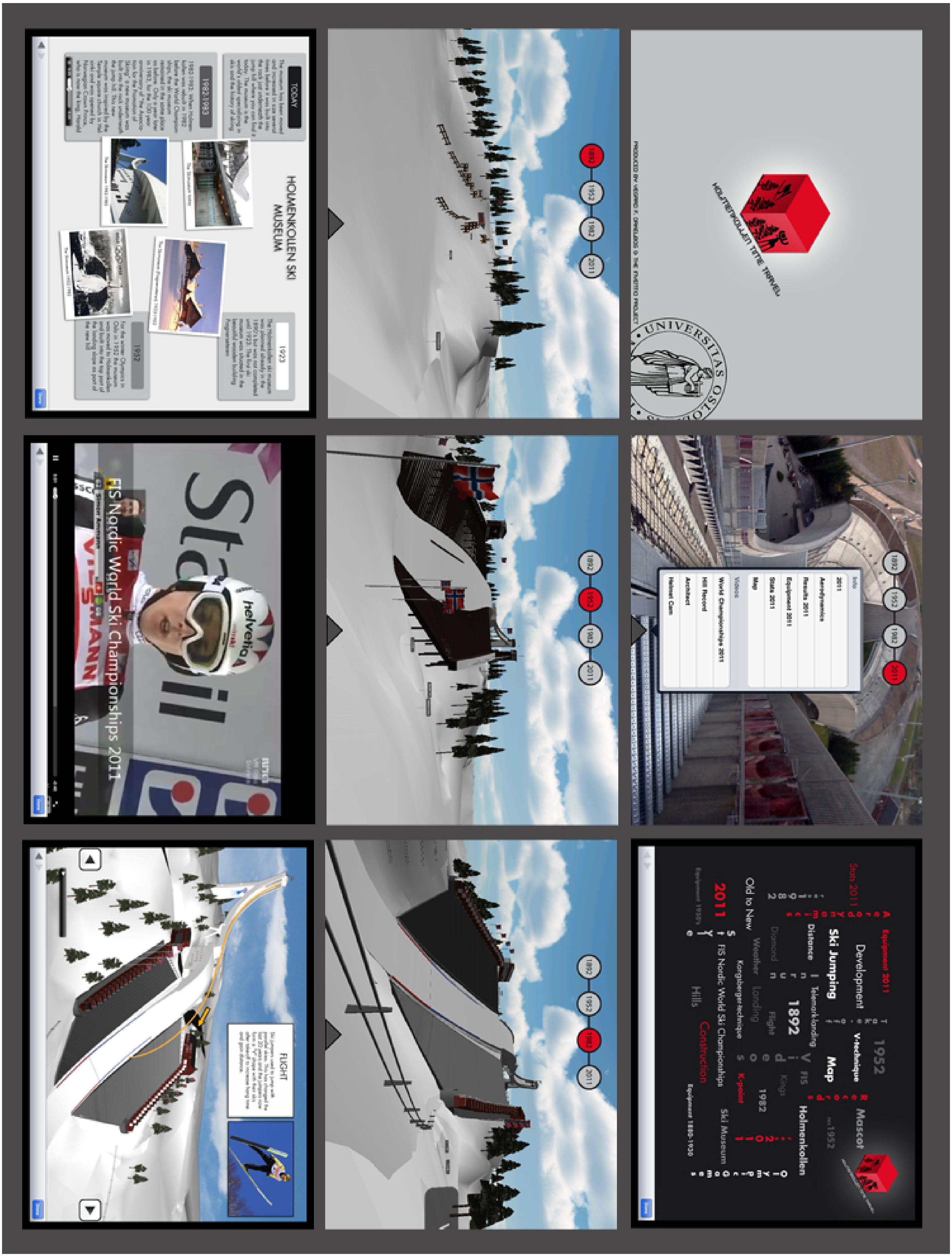
Sensors

- Three-axis gyro
- Accelerometer
- Ambient light sensor

Wireless and Cellular

- Wi-Fi + 3G model: UMTS/HSDPA/HSUPA (850, 900, 1900, 2100 MHz); GSM/EDGE (850, 900, 1800, 1900 MHz)
- Wi-Fi + 3G for Verizon model: CDMA EV-DO Rev. A (800, 1900 MHz)
- Data only3
- Wi-Fi (802.11a/b/g/n)
- Bluetooth 2.1 + EDR technology

Figure 1: iPad 2 from apple.com (Apple, 2011b)


HOLMENKOLLEN SKI MUSEUM
TODAY
1982-1983
1923
1952
1892
1952
1982
2011
FIS Nordic World Ski Championships 2011
FLIGHT
UNIVERSITAS OSLOENSIS
Ski Jumping
Development
Map
Holmenkollen
Mascot
Old to New
Construction
Hills
K-point
Ski Museum

2 General outline of the application

HTT is a fully working *sitsim* prototype. This chapter describes the development, layout, navigation and the functionality of the application from the process started with the idea phase in late December 2010 to the prototype was finished 9 months later.

2.1 Designing Holmenkollen Time Travel (HTT)

The events in 1892 and 93 showed that the inrun of the Holmenkollen hill was far from perfect as the jumpers lost their balance right before take-off. It was decided that the bump be removed from the terrain, and 2000 NOK (equivalent of 135.000 NOK in 2010) was granted for this purpose. This caused a great debate and the newspaper Aftenposten wrote: “Are we going to spend even more money on a ski jumping hill that has already become too expensive?”(Hedenstad et al., 2010 p. 70) Throughout the century Holmenkollen has been rebuilt and expanded no less than 18 times, and the far most expensive reconstruction was the last one. When today’s hill was planned back in 2005 the city council granted a budget of 52.8 million NOK. By 2009 this sum had gone up to 1.8 billion NOK. In the media it was referred to as a new Norwegian record in budget deficit and called a huge scandal. The opposition raged, but only for a short while. The majority of the politicians both locally and nationally not only wanted this arena to be built, but they wanted it to be perfect, good enough to give Norway a FIS Nordic world ski championships to be proud of. This somehow describes how important Holmenkollen is to the Norwegian people. (Hedenstad et al., 2010, Bjørge, 2008, Gram, 2009)

The HTT is my attempt at adding a new feature to the family of *sitsims* made by the INVENTIO project. (Liestøl, 2011b) I had previously participated in designing a *sitsim* of the Forum Iulium in Rome under this project (Fredheim, 2010) (Orkelbog, 2010). The HTT prototype takes the user on a travel through time from origin to present time, experiencing the development of Holmenkollen and the sport of ski jumping.

2.2 Development

HTT was developed through eight iterations:

1. Idea phase – This phase contained in principal the development of the application outline, visual ideas, and content form. I designed a project plan and a flow chart for the application.
2. First test phase – To be sure that Holmenkollen was suited for a SIT-SIM, several tests of GPS and 3G coverage were done, I will discuss testing further in the methodology chapter.
3. Research phase - To build the 3D models of the three selected hills required measurements and scale were needed to build authentic reconstructions. Historical facts, picture and videos were also needed for content production. People from the Holmenkollen ski museum were very helpful during this phase.
4. Modeling phase (3D) - The 3D modeling was done in Autodesk Maya and was the most time consuming part of production. Importing the models in Unity to check the result was an important part of 3D production.
5. Content production (Web) – HTML and CSS was used to design content within the application. Text production as well as image processing were important parts of this work
6. Sound and video production – Voice-over recording and editing for the web content as well as video editing for YouTube.
7. Second test phase (position/content on location) – As soon as the first version of the application was ready for testing I started testing on location. Four tests in total were required before a finished prototype was achieved.
8. User tests (4 focus groups) – Four different user tests were conducted in this iteration.

My work with the *HTT* application started in December 2010 in collaboration with the INVENTIO-project lead by Professor Gunnar Liestøl, Dept. of Media & Communication at the University of Oslo, Norway. CodeGrind AB has worked with all *sitsim* applications of the INVENTIO-project. CodeGrind AB has built the structures and functionality of the applications in Xcode and Unity. Xcode is found in the iOS SDK. iOS SDK includes a complete set of development tools for creating apps for iPad, iPhone, and iPod touch, including the Xcode IDE, iOS Simulator, Instruments, Interface Builder, and more.(Apple.no,

2011) Xcode is a suite of tools, developed by Apple, for developing software for Mac OS X and iOS. The Xcode suite includes a modified version of free software GNU Compiler Collection, and supports C, C++, Objective-C, Objective-C++, Java, AppleScript, Python and Ruby source code with a variety of programming models.(Apple, 2011) The programming language used for controls and functionality inside the application is JavaScript. Unity is a tool for creating 3D video games or other interactive content such as architectural visualizations or real-time 3D animations. Unity's development environment runs on Mac OS X and Microsoft Windows, and the finished product can be run on Windows, Mac, PlayStation 3, Xbox 360, Wii, iPad, iPhone, as well as the Android platform. Unity supports three scripting languages: JavaScript, C#, and a dialect of Python (Boo). All three can make use of .NET libraries which support databases, regular expressions, XML and networking. The Situated Simulations made by the INVENTIO-project have been modeled in Maya or Cheetah 3D imported into unity and given functionality through the programmed features.(unity3d.com, 2011)

2.2.1 3D tool and modeling

Unity supports integration with 3ds Max, Maya, Blender, Modo, ZBrush, Cinema 4D, Cheetah3D, Photoshop.(unity3d.com, 2011) With limited 3D software experience I chose to use the one I already had some knowledge of and that I knew had Unity support: Autodesk Maya 3D. This animation software is a 3D computer graphics software that runs on Linux, Mac OS and Microsoft Window. It delivers comprehensive tools for animation, modeling, simulation, visual effects, rendering, match moving, and compositing on a highly extensible production platform.(Autodesk, 2011) The choice to use Maya caused some problems in the case of map importing (see chapter 2.2.3 maps and terrain).

Figure 2: HTT in use in the arena

First of all I was designing for a tablet computer which has certain hardware limitations. The graphics engine in the iPad is still far from being as good as an average computer. I focused my effort on constructing the terrain and ski jumping hills as good as possible within the constraints, both in scale and in form, and decided to leave out a few buildings on the outskirts of the terrain as well as the ski museum of the 1982 hill. Some details such as railings, proper fences, and details in window frames and so on where left out, and some other details were simplified. In 3D computer graphics, polygonal modeling is an approach for modeling objects by representing or approximating their surfaces using polygons[1].(Wikipedia.com, 2011b) As Unity only supports polygon modeling, all of my models were created using this technique.

2.2.2 Architectural research

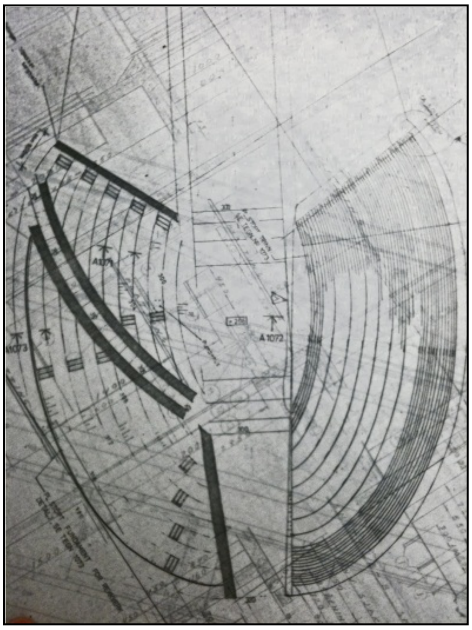


Figure 3: Lower part of the stands 1982

In order to build the 3D structures I needed facts and measurements of the selected hills. I soon discovered that there was little or almost no information regarding the size of the earlier Holmenkollen ski jumping hills to be found either on the Internet or in books. Only pictures, a few videos, rough numbers and measurements were immediately available. As I needed more accurate information, I made contact with the Ski museum at Holmenkollen hoping to find architect drawings.

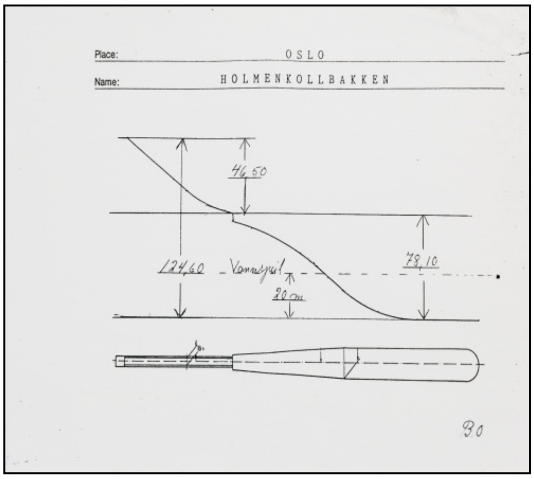


Figure 4: A coarse sketch of 1982 hill

I found drawings of the 1982 hill. (Fig. 2 & 3) They didn't feature measurements from all parts of the hill, but gave very accurate information on some parts. The ski museum has, as I mentioned before, four accurate physical models of Holmenkollen. By combining the drawings and the models at the ski museum with information found elsewhere (e.g. texts, pictures and map readings), I was able to

[1] "A polygon can be defined as a geometric object "consisting of a number of points (called vertices) and an equal number of line segments (called sides), namely a cyclically ordered set of points in a plane, with no three successive points collinear, together with the line segments joining consecutive pairs of the points."WEISSTEIN, E. W. 2011. Polygon [Online]. Available: http://mathworld.wolfram.com/Polygon.html [Accessed].

calculate the measurements of the hill accurately enough.

Collecting information about the 1952 hill was more difficult. There were no drawings available at the museum and little information describing the hill size and profile. In *Store Norske Leksikon* (snl.no, 2011) and on *NRK.no* (NRK.no, 2006) I found rough numbers describing the height of the tower, the hills K-point, building material and features. Comparing the 1952 model with the 1982 model at the ski museum gave me a sense of the angle in the inrun and outrun, size differences and how much mass that was dug out of Besserudtjernet. I used a 3D grid with values of 1 meter per square and lined the models up next to each other in Maya to compare them until I was able to model a satisfactory result.

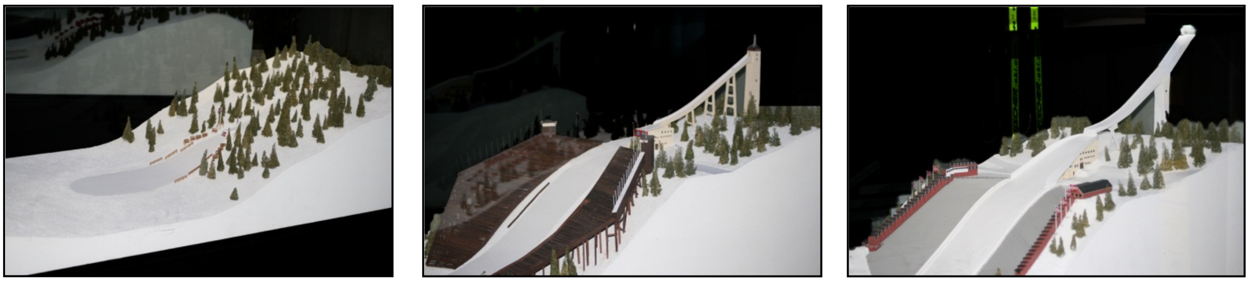


Figure 5: Three physical models from the ski museum in Holmenkollen

Although the first Holmenkollen hill was the hardest to find information about, it was somehow the easiest one to model. As it was built as far back as in 1892 there is hardly any picture material of the hill. Very little is also written about it. The few pictures I found showed a very simple construction, almost like a clearing in the forest with a few single wooden booths to seat the judges and the royal family, and fences separating the hill's outrun and the spectators. The jump has been described as a construction of snow and branches and there were flags at the top and two more by the jump itself. (Hedenstad et al., 2010 p. 74)

2.2.3 Map and terrain

Other *sitsims* have been made on more or less flat terrain. (Liestøl, 2011b) The Holmenkollen Time Travel demanded more of the 3D terrain because of the hilly ground Holmenkollen is built on. As movement in real life is transferred to movement inside the application, the 3D model needed to be as similar as possible to the ground surrounding Holmenkollen for the experience to correspond. Rather than sculpting the terrain by hand from pictures and maps, I chose to handle this challenge as architects do. As they have to follow strict measurements while modeling, the terrain has to be accurate down to the millimeter. To achieve this they order digital maps which they import directly into the 3D software. Their work process was directly applicable to my work.

I ordered digital maps from *Plan og bygningsetaten*, the department affiliated with the municipality of Oslo that serves both private individuals, contractors, architects and others with map prints and digital maps. The maps are ordered either by entering the total number of meters north-south and west-east combined with a center point, or coordinates in latitude-longitude from the top right corner and the bottom right corner of the selection. (byggesak.com, 2011) To find the right coordinates *Norgeskart.no*[2] has accurate maps of Norway with functionality to get the right map coordinates. Thereafter I choose the map data format. This way I got the segment of a map I needed. (kart.statkart.no, 2011)

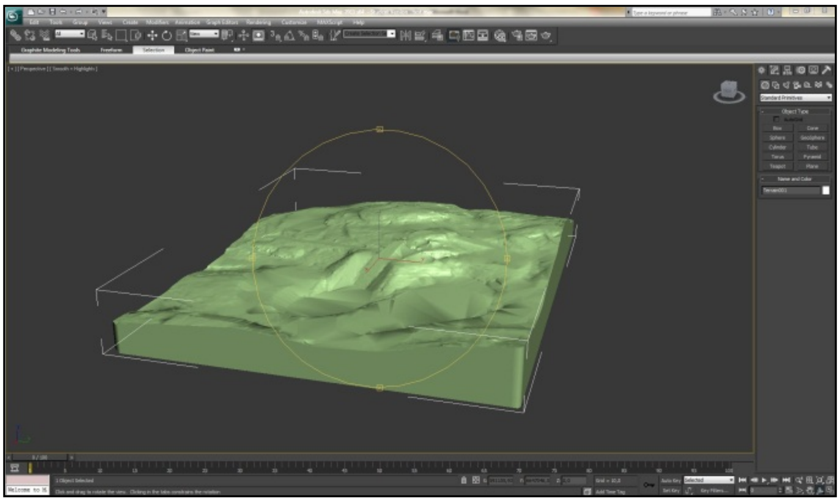


Figure 6: Terrain in 3D Studio Max

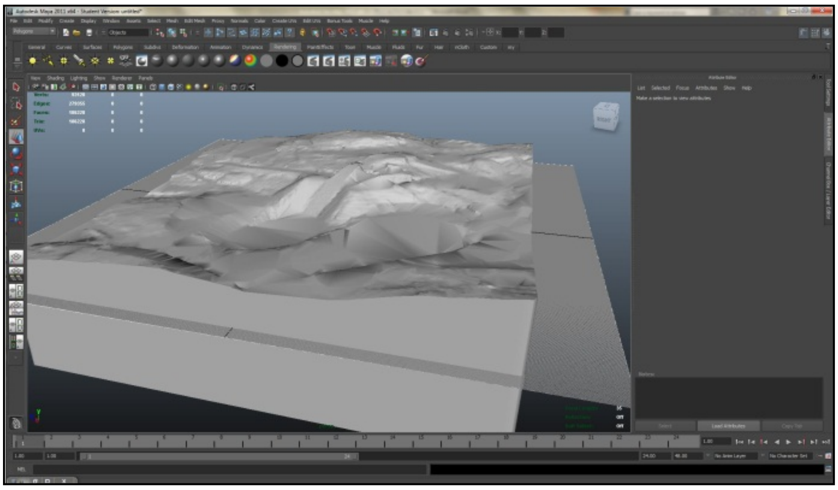


Figure 7: Terrain in Autodesk Maya

Digital maps require an engineer to extract the map segment and produce a digital map in the right file format.(byggesak.com, 2011) I tried importing this 3D terrain (in .DFX and .DWG format) into AutoCAD Maya without luck. Both the .DWG and the .DFX import would only be displayed as two long lines. The alternative was to import the maps into additional 3D software, the *AutoCAD 3D studio Max*, to sculpt and simplify the terrain before I exported the

[2] Norgeskart.no: the governmental online map site

finished mesh in a data format (.FBX) readable to Maya. A challenge was to get the imported mesh down to a sufficiently low number of polygons. Since the graphics engine in the iPad has limitations each of the models would need to be fewer than 100.000 polygons for the application to run smoothly. The unedited terrain alone was around 200.000 polygons and had to be downscaled to about 15.000-20.000. That reduction caused a lot of detail to disappear from the terrain, but not so much as to make the model unrecognizable or to prevent the height differences in the terrain from sufficiently matching the real world. As the Holmenkollen ski jump has been changed the terrain around the hills (1892, 1952 and 1982) has been changed accordingly. The terrain I imported was that of today, so small modifications had to be made to each of the hill views. Picture material and the physical small scale models from wood and plaster found at the Holmenkollen ski museum was used to adjust the terrain to match the time. The biggest change in the terrain is the big dugout of Besserudtjernet. What was once a bog was changed into a big artificial pond of water, and this is now the lower parts of the stands. The dugout was the only way to make the outrun of Holmenkollen longer as the geographical location of Holmenkollen isn't really ideal for expanding the jump hill. For the hill construction of the 1982 hill, there was constructed a foundation of gravel and dirt to support the stands. This foundation has been further developed for today's hill. These are also parts of the hill that have been under continuous change over the years.

2.2.4 Web content

All of the links (Fig. 8) inside of the application leads to webpages. The pages are built in basic HTML and CSS in a 1024x768 resolution to fit the screen resolution of the iPad 2. The web content is built in a manner to enhance readability and navigation. ¾ of the web pages have an embedded sound player which plays back the voice-over clips introducing the topics. The main reason why the content are is in web format and not embedded in the application itself was for me to retain control of the presented material. As INVENTIO did all the implementation in Unity I would not have been able to edit content after giving it to the programmer. Showing content only as web pages is a new solution in sitsim. Usually content, both written and animated, is included in the application. There are positive and negative sides to a solution like this. It can be a challenge some places that it requires a stable and fast internet connection on the other side by storing it on a webserver I maintained control and flexibility.

Figure 8: Link for interaction with web content

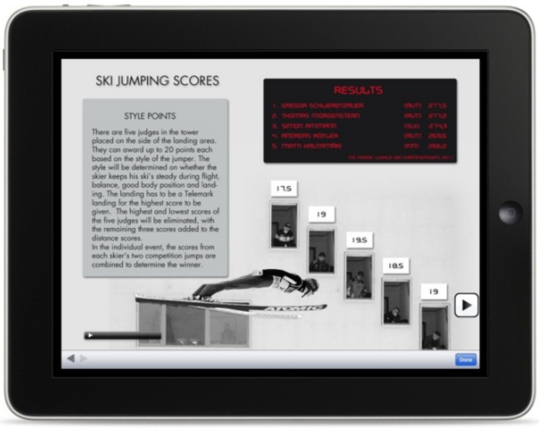


Figure 9: Web content describing style points in ski jumping

2.2.5 Producing sound and video for HTT

Figure 10: Embedded sound player

The voice-over clips were recorded in a studio on the iPad 2 using the QuickVoice recording app. The texts were read in English, and had a length between 20 seconds and 120 seconds. The finished recordings were edited in Adobe Soundbooth CS5. The modifications done to the sounds were basically compiling sound clips into full clips and reducing background noise. The finished voice-over clips were converted into a stereo mp3 format before stored at the web server. The HTT contains a total of 18 voice-over clips.

There have been issues linked with implementation of video inside sitsim. In HTT we found a way to work around this problem. By placing the video clips on the Internet, in this case YouTube, the videos could be shown on the internal video player in the iPad 2 floating on top of the HTT application. It that way the video can be opened in full screen. Video has been important to document jump style and technique in the former hills. They have been edited in Windows Movie Maker.

2.2.6 Collaboration with INVENTIO

As all of the other *sitsims*, HTT was implemented and given functionality by the programmer in the IVENTIO-project (Tomas Stenarson/ CodeGrind AB). The HTT was put together with 4 different views: 1892 (3D), 1952(3D), 1982(3D) and 2011(AR) where the 3D models where implemented as 3 different instances in the application. The terrain in all of these models where practically the same except for some modifications done around Besserudtjernet (the submersion in the terrain at the end of the outrun), and up along the stands which was modified to match the terrain from that time.

The collaboration with INVENTIO was focused around two specific tasks; positioning the 3D world (latitude and longitude) to correspond with the real position of the Holmenkollen ski jumping hill to give it sufficient locative abilities; and placing the links in the terrain (see chapter 4.1.3). Position is given to a certain location in the 3D model that corresponds with the same position in the real terrain. First this position was found on the map of Holmenkollen (kart.statkart.no, 2011) and given coordinates (longitude/latitude) to represent it. These coordinates were then added to the same position in the 3D terrain in each of the three models. To switch between the views a menu was made which loads each of the three 3D entities.

2.2.7 Perspectives

The HTT's four main views or perspectives were selected because of their significant impact on Holmenkollen as an arena. Each of the four perspectives are presented in 2 different ways; either as 3D or as Augmented reality. To switch between the different views, the user will interact with the menu shown as "four circles on a string" in the top part of the screen. The circle representing the active view has a red color while the others are grey. The application opens up in a 2011 view. The hill here is shown in a camera-view on the *iPad 2*. The three other views are presented as a recreation of historical hills in 3D. The application consists of two main features. The first feature allows the user to switch freely between the different years or views as she move around the ski jump hill. The second feature consists of information about Holmenkollen, ski jumping and relevant facts about this location and the sport. Links to this information are placed in the terrain. The placement of links in 2011-view turned out to be difficult as placement of links inside the *sitsim* in an AR view can be very inaccurate. Taking this into consideration the best solution, in my opinion, was to add a standard list menu for this view. (Fig. 10) This menu is accessible from the dock (grey arrow, center on the bottom of the screen) and gives the user access to all of the relevant 2011-content in the application. When the application is turned on it will automatically try to find the device's position in the Holmenkollen arena using the GPS. If the user is situated at a different location than Holmenkollen, the device's position will be set to a *default position* just beneath the stands on the left side of the hill. As the application is meant for use solely on location, this feature is primarily made as a test feature, but it can also be used to access information and re-live the 3D models when returning back home or to the hotel.

2.2.8 Navigation

Navigation inside HTT, like other *sitsims*, is created as an extension of how we move and see as human beings. The GPS in the unit picks up your longitude and latitude and place you in the exact right position inside the 3D world of the application. As the terrain in the 3D world is designed accurately from an imported map it should create recognition straight away.

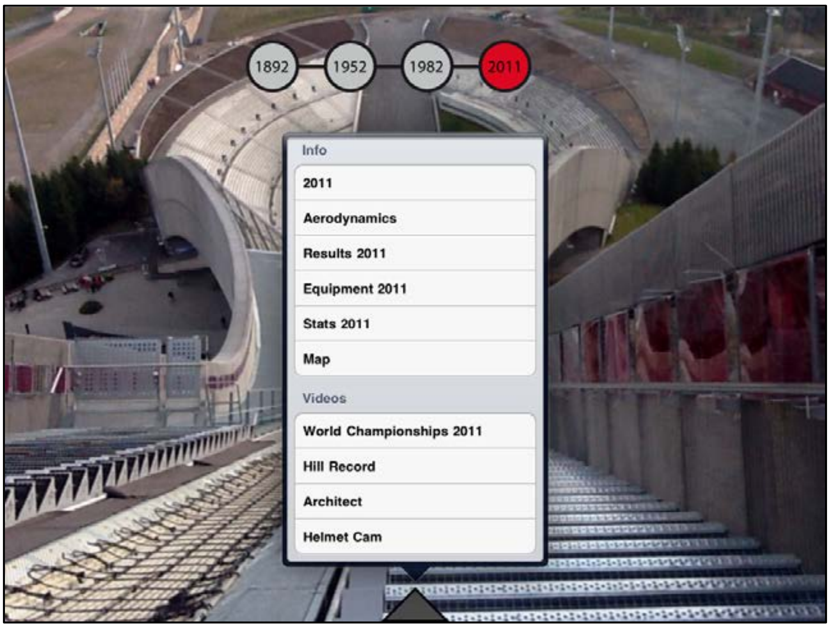


Figure 11: AR-view with dock menu

There are three separate 3D worlds in this application. The last view or year, 2011, does not use any locative services at all as it shows what you see through the lens of the camera. As the user starts moving, the movement will be picked up by the GPS and this is reflected inside the application. As the user turns around or tilts the device the orientation features in the device come into play. The compass and the accelerometer register these movements and transfer them on to the screen. If the user turns 180 degrees in real life, she will also turn 180 degrees inside the 3D world. If the screen is tilted upwards the view will be accordingly. These different navigational tools should create a near perfect correlation between what is seen on screen and what is seen in real life as long as the GPS coverage is good.

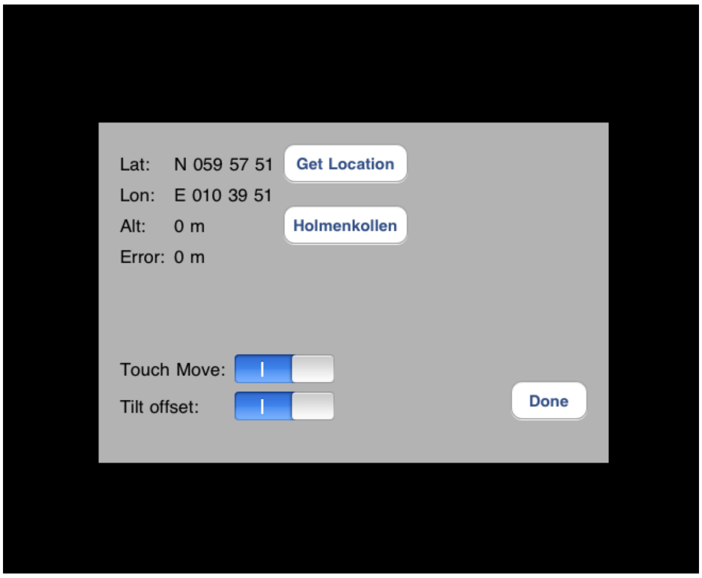


Figure 14: Configuration menu

As I mentioned before, it is possible to navigate within the application even if the user is somewhere else. This is a feature primarily for testing purposes, but it can in also be used on location. By placing four fingers on the screen simultaneously a menu will pop up on the screen (Fig. 11) providing the position coordinates and two buttons for control menus. The touch move button will enable the feature that gives the user a touchpad in the lower left corner of the screen. Sliding the finger upwards on the screen with one finger moves the user forward in the terrain, sliding the finger to the right makes the user move sideways to the right and similar movements makes movements to the left and backwards. Using this feature the user can move freely in the terrain reaching all of those hard to reach places. This feature will take the user away from the first person perspective where the user’s movements and visual perspective correspond with the screen which makes *sitsim* applications so special.

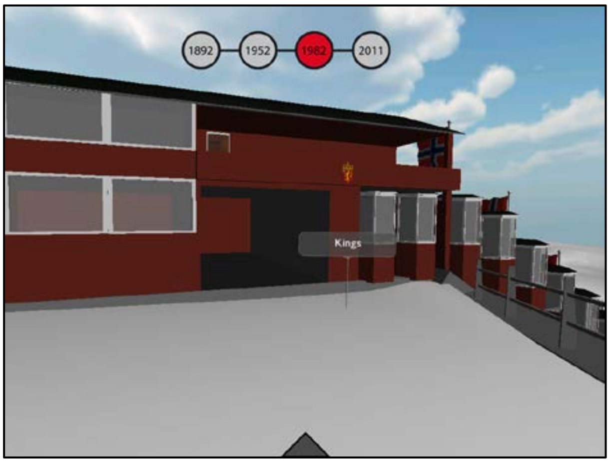


Figure 13: 1982 Hill - Link to the Kings Grandstand

Figure 12: Web content – the Kings Grandstand

As the user walks around exploring the arena she will be faced with the links mentioned earlier which are placed strategically in the terrain. These link to web content of different type and format. The placements of these links are done in such a manner that objects in the 3D world match the content itself. An example: The link "king" is placed just underneath the king's grandstand in the 1982 Holmenkollen hill. (Fig. 12 & 13) This is the balcony where the royal family would stands during big ski jumping events in Holmenkollen. When the user hits this link on the touchscreen the web browser opens and floats on top of the 3D model showing pictures of the different kings who have attended events at Holmenkollen and a voice-over clip controlled by the small embedded player in the lower left corner of the web page. Hitting done in the lower right corner will take the user back to the 3D model.

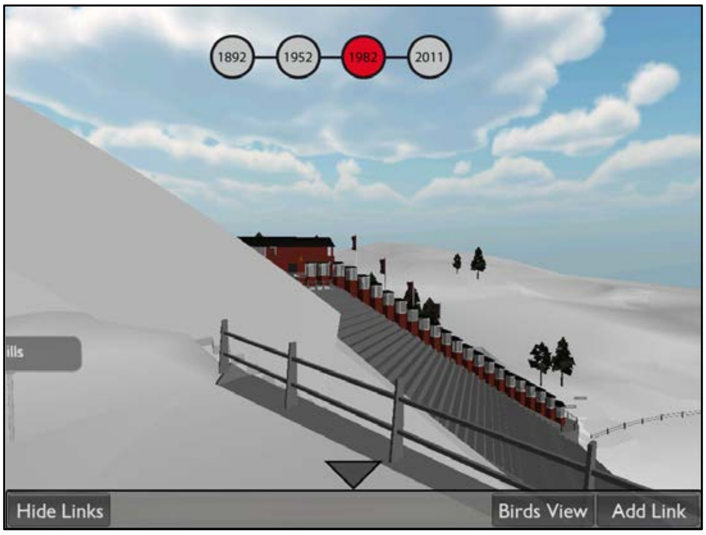


Figure 15: Dock Menu

The grey arrow (the dock) found in the bottom center of the screen, has a different functionality in the 3D views than in the AR view. (Fig. 14) It will give access to a different type of menu in the 3D views than it does in the AR view. The 3D menu has three features. You can hide all the links, and thus remove all interactivity so that you can view the structure and terrain in the reconstruction without any distractions or elements being in the way. This feature can be toggled on and off as you please. The second feature is the birds' view. The birds' view will elevate the user's position in the terrain and give a top down perspective. (Fig. 15) The level of elevation can be controlled using the "lever" on the right side of the screen. The "lever" can be slid up and down with a stroke of the finger. In this perspective the user loses her

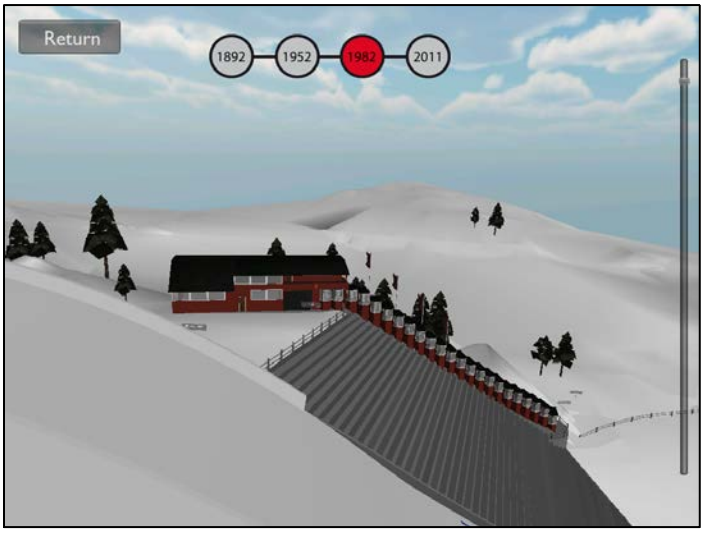


Figure 16: In "Birds View"

ability to interact with the links as she is in birds' view. The user will have to hit the return button in the top left corner of the screen and return to the ground to be able to open the links. The third feature is adding links. This button creates a link to a specific location in the terrain chosen by the user. The user can link to webpages and add text information describing the link. The link will be saved on the application database for other users to see. This feature has not been prioritized in the user-test.

2.2.9 HTT web content

The Holmenkollen operations manager made a comment during the interview after testing the application that I believe describes my reasons for including the content in HTT:

"I liked the links because they give the user facts about Holmenkollen and ski jumping. They are really important for the experience as it becomes more vivid and you gain some knowledge as well." (Orkelbog, 2011a)

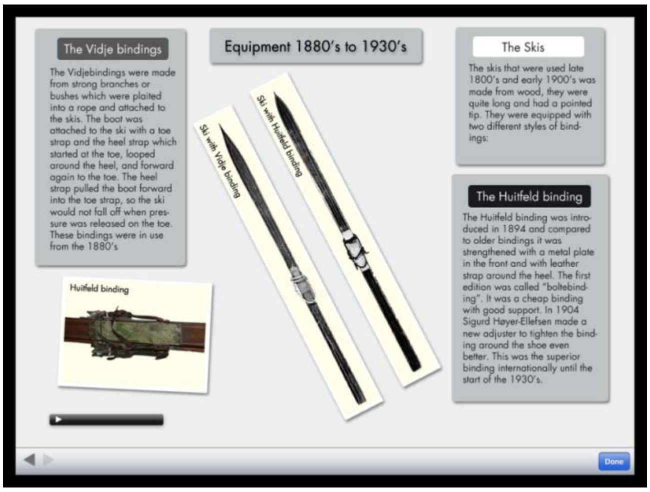


Figure 17: Ski equipment from 1880-1930's

The links takes the user to a web site that gives information about Holmenkollen. This includes basic ski jumping rules, physics, technique and equipment. As mentioned earlier in this chapter the links are positioned in the terrain, and as the user close in on them they will become bigger until they are big enough for the user to "tap" them. The web content is made up of text, pictures, sound and illustrations. You will also find links to external internet content like the Holmenkollen website, FIS website and Wikipedia and to videos on YouTube. The historical content describes how and why the hills were built, and give insight into ski jumping; equipment and competitions in the hills. (E.g. fig 16 & 17) The pages have voice-over played by an embedded player in the lower left corner of the page. Illustrations or renderings from the 3D modeling are used to

Figure 18: Distance points in ski jumping

describe ski jumping technique, aerodynamics and the hill construction. These can either be presented on a single page with voice-over or as a series of pages navigated by arrow buttons on each side of the page to go forwards or backwards, i.e. the four stages of the ski jump. (Fig. 18)

Other links describe the different hill records of Holmenkollen from 1892 until today, how points for style and distance are given, facts about the weather conditions, illustrations showing the different hill profiles, map of the area and so on. Web pages can be seen on (http://www.minus.im)

As links are only accessible from a specific location in the terrain it can be a long walk back if you want to see the content again. In order to stay true to the perspective in *sitsim* and still achieve usability I chose to make an information point within the 3D world itself. (Fig. 19) Through the "info" link the user can enter all the application's web content from one location.

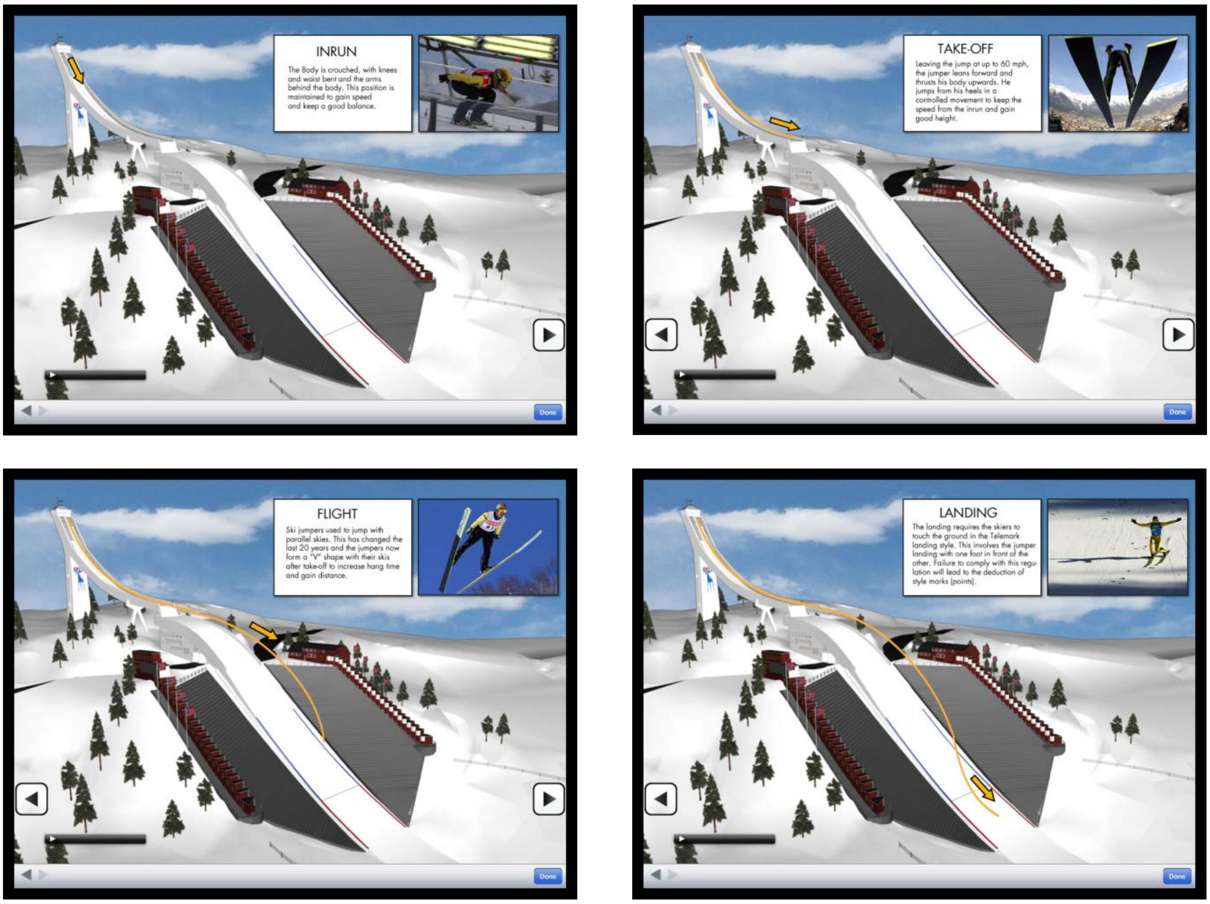


Figure 19: The four stages of the ski jump

The info sign is reachable in all the three 3D models and is placed on the same spot in the terrain in all three models. When the link is clicked the information is structured in a "wordcloud". The different years are represented by different colors. Each word will take the user to a different topic and the two arrows in the bottom left corner enable navigation between the web pages. The "videos" link inside the "wordcloud" will take the user to a separate page with a new "wordcloud" presenting all the videos. (Fig. 20) (The wordcloud is also accessible in the 2011 view from the dock menu). The videos consist of material from 1952 to the present. Videos are shown in the YouTube embedded format and open like the web pages by floating on top of the 3D view. The videos show changes in technique from just after the World War II: the three best jumpers in the Olympics of 1952, the world championships of 1982 and the world championships of 2011, hill records and an interview with the architect Julian de Smedt who designed today's hill. These videos give a more vivid presentation of what Holmenkollen was like. They give the user an opportunity to see the hills in use with the right equipment and with the right technique. They also recreate the atmosphere at the ski jumping events making them the HTT come alive.

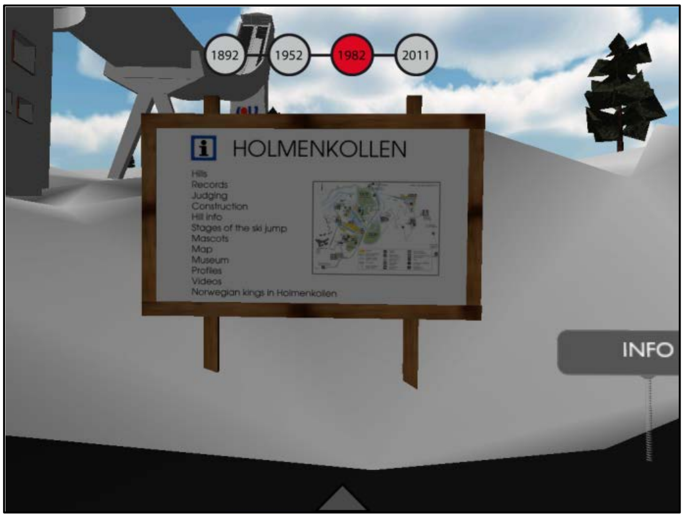


Figure 20: INFO-link beside the Holmenkollen info sign

Figure 21: INFO wordcloud & Video wordcloud

3 Theoretical perspectives

This chapter serves as a theoretical backdrop for this thesis. Location Based Services, Situated Simulation, Augmented Reality and Place Specific Computing are the four conceptions in focus, and will be thoroughly introduced in relation to HTT. Location Based Services in the commercial sense is more than car navigation. I will introduce basic functionality and differences in functionality in the fields it is applied. Augmented Reality theory and the understanding of the term are important to understand the basic functionality, navigation and interaction of a *sitsim*. AR is in this chapter introduced and given a historical context. HTT is part of a series of *sitsims* developed since 2007; I will describe the term *sitsim* in the context of AR on the basis of prof. Liestøl's research. Last I will introduce Place Specific Computing, a concept within interaction design that focus on digital design where the users are determined by the place we design for, rather than being defined by a target group disconnected from a place. This place-centered perspective is interesting in a Location Based Service like the HTT because of *sitsim* applications have a clear focus on place and representation of place.

3.1 Location Based Services

Location based services (LBS) or locative media is a software application on a mobile device that requires geographical location knowledge of where an entity is located. The term entity means the object triggering the location information can be human or non-human. A pallet of groceries tracked for logistic purposes, can be an example of a non-human entity. (Junglas and Watson, 2008 p. 2) In LBS the user's location works as an organizing principal for functionality and information provided by the application. Location-based services can be query-based and provide the end user with useful information such as "Where is the nearest café?" or they can be push-based and deliver messages or adverts to customers who are in a specific geographical area. In LBS there are always at least two entities involved, where one is always the object of LBS, that is, the entity on which location information is recorded and there is always a recipient of the location information. LBS researchers distinguish between location tracking services and location-aware services. A car navigation system is a type of location-aware system where location information is provided to the driver on a request, and the driver gets a real-time navigation service. Location-tracking services provide information about a user's location to entities other than the user i.e. a typical LBS service for public transport gives the customers real-time information about when the bus will arrive at the stop. (Junglas and Watson, 2008 p. 3) While LBS offer significant opportunities for a broad range of markets, they present users significant privacy threats. I.e. anonymity threats like the potential exposure of service uses, identification in services with sensitive information or location privacy issues. Location privacy has been a serious problem as criminals have robbed people's houses after checking their location status on Facebook. (Mello.Jr., 2010)

Locative media projects take on many forms and we find more and more of them in our daily lives. Some LBS applications have only scientific interest while others are commercially interesting. Some help you reach the bus, others to buy cinema tickets. *Layar* and *Wikitude* are applications that are fully operational AR platforms for which developers can produce different functionality and layers. *Instagram* gives location to your photos and shares them, while *Foodspotting* helps you to find a restaurant close to you. Social networking services like *Facebook* and *Google+* let you communicate with and find your friends if you use their mobile application services, while *Foursquare* takes location-awareness one step further and gives rewards and badges to the users if they fulfill certain tasks at certain locations. Implementation of LBS in HTT is essential for its functionality and perspective. HTT is a fully working LBS prototype that shows new features and possibilities in the genre. If it should be commercialized it would need to be further developed (see chapter 5.5).

3.2 Augmented reality

Augmented reality (AR) is often thought to be a new phenomenon, even though we have seen quite a few commercial AR applications on the app[3] market the last 5 years. The truth is that AR goes a long way back. For many of us Virtual Reality (VR) also called Virtual Environments (VE) is a much more familiar term. VR is "a computer-generated, interactive, three-dimensional environment in which a person is immersed." (Aukstakalnis and Blatner 1992 in (Vallino, 1998a p. 6) There are three main points to this definition. The virtual environment is three dimensional and provides an adequate level of realism. The virtual world is interactive and finally the user requires real-time response from the system to be able to

[3] The term is shorthand for "application" in the IT community. An app is a piece of software. It can run on a computer, Internet, mobile phone or other electronic device. It newly became popular for mobile applications in smartphones and tablets especially due to the advent of Apple's iTunes App Store and Android market in 2008.

interact with it in an effective manner.(Vallino, 1998b) VR has often been portrayed in a scenario where man and machine grow closer together. In VR the user will wear goggles and controls (can often be a suit and gloves) that transfer the users body movements into the synthetic environment. In the 1980's and 90's VR was a symbol of how the technological future would look like, and featured in several blockbuster movies. Tron, the Lawnmower man, eXistenZ and the Matrix are all movies that have been part of shaping the common "knowledge" of VR. The presence of VR has since then faded, as videogames has become more immersive and AR has gotten a more significant position. The first AR system was built all the way back in 1968. It had a head mounted display and movement was tracked by one of two different 6DOF trackers: a mechanical tracker and an ultrasonic tracker. The processing power was limited and only wireframe drawings could be displayed in real-time. (ChristianDopplerLaboratory, 2009) The term AR was first introduced by Tom Caudell and David Mizell in an article they presented in 1992 about how airplane manufacturers could use see-through display head set combined with head position sensing and workplace registration systems to assemble and repair airplanes:

> This technology is used to "augment" the visual field of the user with information necessary in the performance of the current task, and therefore we refer to the technology as "augmented reality" (AR).(Caudell and Mizell, 1992 p.660)

AR was for the first time systemized when Milgram and Kishino in 1994 wrote the paper *"A taxonomy of mixed reality visual displays"*. In their article, which focused on mixed reality, "the merging of real and virtual worlds"(Milgram, 1994 p. 2), they discuss the possibility of having both "virtual space" and "reality" within the same visual display environment. To explain this mixture of classes of objects presented in a particular display situation they introduced the "virtual continuum" (VC) (Fig 21), where real environments are shown in one end of the scale and strictly virtual environments in the opposite end. As indicated from the VC the mixed reality environments lie between the extremes of the virtual continuum.

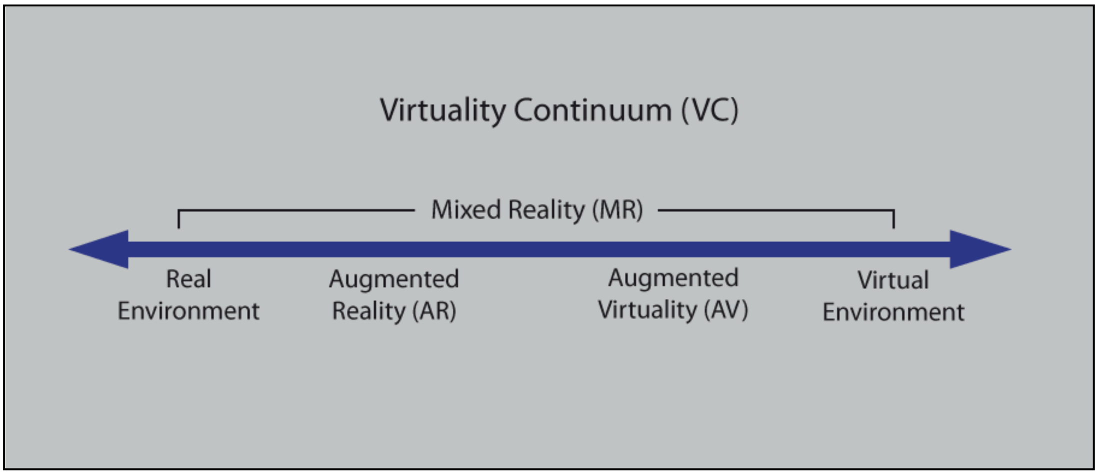


Figure 22: from Milgram's "A taxonomy of mixed reality visual displays"

"Real" objects are defined as *"objects that have an actual objective existence"* and "virtual" as *"objects that exist in essence or effect, but not formally or actually."* (Milgram, 1994 pp. 6-7) The distinction between "real" and "virtual" objects is defined by three different aspects. First, in order for a real object to be viewed it can be viewed directly, or be sampled and resynthesized via a display device. For a virtual object to be viewed, it has to be simulated as it does not really exist.

Secondly, image quality influences the user's perception of what is "real". A real object can be watched directly or unmediated, e.g. through a glass window, a microscope or binoculars. Non-direct viewing is when real objects are sampled directly through an imaging system for us to see. It could be for example using a camera or ultrasound before it is resynthesized on a display. Virtual object cannot be sampled directly, they can only be synthesized. Both real and virtual synthesized images can be made to look extremely realistic today, therefore is it really important to emphasize that just because the image looks real it doesn't mean that the object it represents is real.

The third aspect is the distinction between real and virtual images. This difference is explained by understanding the field of optics. A real image has luminosity at the place it appears to be located; this counts for both direct viewed object as well as non-direct viewed object. The object is physically present. A virtual image on the other hand has no luminosity at the location which it appears, like holograms and mirror images. Virtual images can therefore be seen as objects which appear transparent, objects that don't occlude other objects positioned behind it. (Milgram, 1994 p. 7)

To describe the idea of *Mixed Reality* (MR), Milgram's taxonomy has three dimensions; *Extent of World Knowledge (EWK)*, *Reproduction Fidelity (RF)* and *Extent of Presence Metaphor (EPM)*. The world knowledge is determined by whether the superimposed graphics have knowledge of the objects in the environment they describe or are related to. Knowledge is understood as *where*; which "refers to cases in which some quantitative data about locations in the remote world are available", which means that the computer knows where an object is but doesn't provide any enlightenment at all about what is at that location. Knowledge can also be understood as *what;* which is some knowledge about objects in an image but no idea where they are. (Milgram, 1994 p. 10) If the computer has no knowledge, the graphic objects will just float arbitrarily within the scene and have no direct connection to the world. Graphics displayed in TV sports events that give score service, contain only information, and interact no further with what you see on screen. Wikitude[4] on the other hand holds knowledge about what physical location (coordinates from the GPS) in the real world certain objects have. Like illustrated in (Fig. 22), the Vigeland Sculpture Park in Oslo is seen through the Wikitude AR app and the Flickr[5] filter. Users see other people's photos from the location they were taken. This knowledge creates a stronger coherence between the elements in the MR.

Figure 23: Traditional AR app for iPhone

Reproduction fidelity (RF) deals with the issue of realism in MR displays. Image quality is important in the sense of immersion or presence within the display. The higher the resolution the more real the experience will be. Milgram says that *"the term Reproduction Fidelity therefore refers to the quality with which the synthesizing display is able to reproduce the actual or intended images of the objects being displayed."*(Milgram, 1994 p. 11) He refers to image quality in both real and virtual objects.

[4] Wikitude World Browser is an augmented reality (AR) platform available for the iOS and Android operating systems for smartphones.
[5] Flickr is an image hosting and video hosting website, web services suite, and online community

> If the maximal image quality is reached there would be no qualitative way for a human observer to distinguish between whether the image of the object or scene being displayed has been generated by means of data sampling or whether it arises synthetically from a model.(Milgram, 1994 p. 11)

Extent of Presence Metaphor describes to what extent the user is intended to feel present in the displayed scene. The level of presence is described on a scale that is defined by the display it is presented on. It is extending from the metaphor where the observers peer from the outside into the world from a single viewpoint, to the maximum level of presence which is described as indistinguishable from viewing reality directly as the observer's sensations are ideally no different from those of unmediated reality. To achieve multiple scopes of view the observer's movements need to be tracked by tracking sensors on a head mounted display (HMD) or GPS. (Milgram, 1994 pp. 11-12)

In need of an in-depth analysis and a definition of the AR, Ronald T. Azuma introduced the article "A survey of augmented reality" in 1997. His motivation for this contribution was rooted in the potential benefits he saw in Augmented Reality. AR enhances perception of and interaction with the real world, information that the user cannot directly detect with his own senses and information that helps a user perform real-world tasks. He introduced a new definition of the term AR;

> AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it. Ideally, it would appear to the user that the virtual and real objects coexisted in the same space, similar to the effects achieved in the film "Who Framed Roger Rabbit?(Azuma, 1997 p. 2)(Fig. 23)

Figure 24: "Who Framed Roger Rabbit?"

Azuma specified that even if some researchers required AR to include HMD's, he would avoid limiting AR to certain technologies. Instead he introduced three criteria that define AR systems; it combines real and virtual, it is interactive in real-time and registers in 3D. (Azuma, 1997 p. 2) This definition was somewhat modified in 2001 to meet advances in the field; Combining real and virtual objects in a real environment, runs interactively and in real time, and registers (aligns) real and virtual objects with each other. This definition does not restrict AR to certain technologies, specific senses or whether the objects displayed are real, virtual or both.(Azuma et al., 2001 p. 34) By introducing this wider definition of AR he has been able to make room for technologies which are dominant today like mobile AR.

AR has several weaknesses, like portability, focus and contrast which I will not go into here, but some issue are important for AR systems to be accepted. There needs to be a tie between the real word and the virtual content to trigger interest within the user.

> In well done traditional AR there is a very strong visual tie between the virtual content and the physical world. This is a general goal of AR in fact, to have the virtual content look like it is actually present in the real world. This is important both for purely functional reasons, and because it introduces a higher level of immersion in the Augmented Reality world.(Wither et al., 2011 p. 815)

This immersion does not need to be equally important for all applications, but for situated simulation like the HTT it can make a big difference.

> In a AR browser style application immersion is not as important because users are primarily interested in task completion, not exploring the AR environment. In many entertainment or game applications though, the experience is primarily about exploring the environment around the user, making immersion in that environment very important. (Wither et al., 2011 p. 815)

Wither et al. concludes that the strong visual ties between the virtual content and the real world are just as important as a high level of immersion. One of the most basic problems limiting AR applications is registration. The real and virtual objects in an AR environment must be properly aligned or the illusion of the joint environment will be compromised. Registration in modern mobile augmented reality systems use one or more tracking technologies like; GPS, accelerometers, digital cameras and/or other optical sensors, gyroscopes, compasses, RFID, fiduciary markers and wireless sensors. Technologies like these offer varying levels of accuracy. Registration problems also exist in VR applications but they are not as serious as in AR. The reason for this can be explained with a basic example. (Azuma, 1997 pp. 9-18)

> A user wearing a closed-view HMD might hold up her real hand and see a virtual hand. This virtual hand should be displayed exactly where she would see her real hand, if she were not wearing an HMD. But if the virtual hand is wrong by five millimeters, she may not detect that unless actively looking for such errors.(Azuma, 1997 p. 18)

Furthermore a phenomenon known as *visual capture* makes it even harder to notice registration errors.

> Visual capture refers to our tendency to allow visual images to dominate our perception. For example, when we watch a movie in a theater, we tend to think that the voices we hear come from the moving images on the screen, rather than from the speakers that could be located all around the theater. (alleydog.com, 2011)

Similarly a person would believe that her hand is in the same position as the virtual hand she sees because of visual capture. This effect increases the amount of error toleration with the user of the VR application. In an AR application the demand for accuracy is much more important. If the application was similar but with a see-through head mounted display the user would see both her hand and the virtual hand. In this scenario the registration error would be quite evident as the two hands would be seen simultaneously in different positions.(Azuma, 1997:18) With film this wouldn't be the case as the director can carefully plan each shot adjusting each frame to achieve perfect registration. In the interactive AR system such adjustment isn't possible as the system can't control the user's movements. The user looks where she wants and the system must respond in a fraction of a second. (Azuma, 1997 p. 19)

In more recent years a lot of new AR applications have been developed but many of these also suffer from poor registration as they rely primarily on the built-in sensors mentioned earlier for tracking. These sensors, especially those used in commodity products, don't provide sufficient accuracy for convincing tracking. Thus the user experience of the application decreases.(Wither et al., 2011 p. 1)

In 2001 Azuma introduced what he saw as the final challenge for AR applications, social acceptance.

> Given a system with ideal hardware and an intuitive interface, how can AR become an accepted part of a user's everyday life, just like a mobile phone or a personal digital assistant (PDA)? (Azuma et al., 2001 p. 43)

He described the issues as fashion concerns "will users wear a system if they feel it detracts from their appearance?", and privacy concerns "we can also use the tracking required for displaying information for monitoring and recording". (Azuma et al., 2001 p. 44)

AR has been around for a while, but has never been accepted commercially because of its big, bulky and terribly expensive equipment. When I was younger I had the pleasure of watching the Lawnmower Man which introduced me to Virtual Reality. It intrigued me, and I wanted to try, but not many people have gotten that chance and neither did I. In the last 5 years there has been a great evolution in the mobile phone market, as a result of convergence and hardware advances, people are walking around with portable computers capable enough to match laptops in processing power and graphics. They have locative and orientation abilities and good quality cameras. Smartphones have become the complete platform that AR needed to overcome the challenges that Azuma presented in his paper back in 2001.

The privacy concerns are still there, but are on the brink of changing, as more and more applications are designed with locative functionality. The uses of locative services are changing the social acceptance of tracking and monitoring the physical location of people. Facebook and Google+ are social networking services that incorporate these features helping users to put their own location on the map and also to track their friends. Glympse is an application which helps the user to share her location with anyone for a specified period of time. This could be to get home safely, or to track guests for a dinner party so the host can have the dinner ready at the exact right moment. (glympse.com, 2011) GPS navigation like TOM-TOM is a locative service that is dedicated to give map directions. (tomtom.com, 2011) Instagram will give geographical position to photographs you shoot (Instagram, 2011), and Starwalk will use locative and orientation services to show you the different constellations in the sky (vitotechnology.com, 2011). These are all examples of how our world gets swamped with services that make us give out our own location and enhance people's tolerance for giving up their privacy.

3.3 Situated simulation in an AR perspective

Sitsim has been described as a type of augmented reality. The application is used to augment specific places with additional information about the environment. Liestøl describes it as follows;

> A situated simulation is an example of a non-mixed 'clean screen' solution. When using a situated simulation, the user's visual perspective in the real physical environment is almost identical to the visual perspective in the 3-D graphics environment displayed on the screen. As you change position and move the phone in the real world, the perspective (or view) on the screen is updated and changes accordingly.(Liestøl et al., 2011 p. 175)

In 2011, Liestøl analyzes in detail *sitsim* in the context of AR. He had received critique regarding whether *sitsim* really could be defined as AR or if it rather should be seen as mobile VR or at most MR. Liestøl chose to look at *sitsim* in the context of Azuma's definition; *"AR* *combines real and virtual objects in a real environment".(Azuma et al., 2001 p. 34)* Liestøl concludes to the first statement that in *sitsim* the actual real environment is combined with a graphical reconstruction of historical objects and a historical site. The real and the virtual occupy the same space and there is a congruity in the real and the virtual environment. A legit question now could be whether the definition actually meant that real and virtual objects should be combined on screen, or if it refers to the complete AR experience. In the article "Indirect Augmented Reality"[6] (2011), Wither, Tsai and Azuma give the following comment:

> Liestoel et al. Have developed a technique they call Situated Simulations which is quite similar to Indirect AR. Their approach uses a hand built virtual world that is associated with a real place. As the user moves about in the real world, their avatar is moved through the virtual world displayed on a smartphone. Unlike Indirect AR though the virtual world they use is not as high fidelity of a representation of the real world as panoramas provide. The ultimate expression of Situated Simulations and Indirect AR are likely quite similar though. (Wither et al., 2011 p. 812)

In the article they compare AR and *sitsim* and describe both as mediations of reality. In that way it seems like they agree with Liestøls claim that sitsim should be understood and dealt with in the context of AR.

Azuma's second statement claims that *"AR runs interactively, and in real-time"*.(Azuma et al., 2001 p. 34) Liestøl concludes that the *sitsim* runs in real-time. The *sitsim* responds in real-time to the user's movements on both a horizontal and vertical axis. In addition the user may engage in real-time interaction that gives immediate response. This interaction is triggered by multimodal links i.e. photographs, flying virtual camera, 3D scanned artifacts for detailed viewing, quiz etc. that is part of the virtual environments in *sitsim*, similar to what you can find in certain video games.

In the third part of the definition Azuma describes that AR *"registers (aligns) real and virtual objects with each other"*. (Azuma et al., 2001 p. 34) In a dynamic environment in traditional AR, occlusion can degrade the experience because they break the link between the physical and the virtual content and can look visually unappealing i.g.:

> It looked like two different scenarios. It's almost like the building was just slapped on top of reality. There was also a secondary problem in this case with the AR approach. Because the virtual content was a large model, it occluded a large part of the real world. (Wither et al., 2011 p. 820)

[6] Indirect Augmented Reality is a project where the live camera view used in video see through AR is replaced with a previously captured panoramic image. By doing this they allegedly improve the perceived quality of the tracking while still maintaining a similar overall experience.

Liestøl describes accuracy in registration as something that is more important in mixed solutions, but that even in *sitsims* good registration is a necessity to achieve acceptance by the user. In a scenario where the alignment slips the real and the virtual can be viewed as separate entities and the virtual environment becomes accidental and irrelevant.

> In a situated simulation one might say that the digital application and the virtual environment itself is only half of the experience. The real site and surroundings are a necessary context and environment for the system to function according to the design intentions. (Liestøl, 2011a p. 314)

Situated simulation does not mix real and virtual environments on the same screen and is therefore hard to place in Mailgram's virtual continuum. A problem with the virtual continuum is that it is one dimensional and only opens up for mixing at the level of the display. This fact rules out some of today's applications as they utilize new smartphones with location and orientation technology, which don't have direct or integrated mixing on screen. The continuum was designed many years ago when handheld computers were not even thought of, and therefore it does not have room for some of the solutions we see today. Just because Milgram's and Azuma's definitions of AR don't fit the coupling of real and virtual environments that *sitsims* represent does not mean that the traditional definitions are

Figure 25: Liestøl's revision of Milgrams VC

incompatible. Liestøl has revised Milgram's virtual continuum to contain a two dimensional field which opens up for new variations of AR. (Liestøl, 2011a pp. 311-317) This revision makes it possibility to combine real and virtual environments that are not connected on the screen but by alignment such as *sitsim*. (Fig 24 & 25)

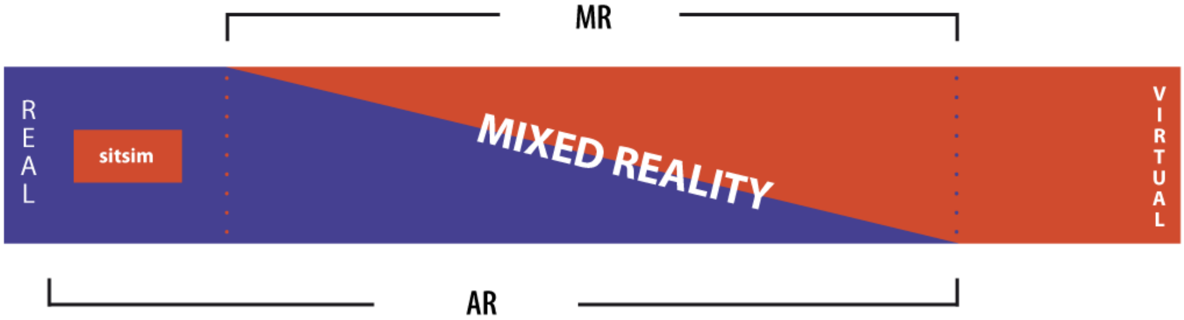


Figure 26: Liestøl's revision of Milgrams VC

Situated simulations have been developed by the INVENTIO-project and Gunnar Liestøl since 2008 and have been made in 8 versions all with historical content: The Oseberg Viking ship, Mission Dolores, The San Francisco Earthquake 1906, the Parthenon, the Temple of Julius Caesar, Forum Iulium, the temple of Devius Iulius and Borrehallen. The last one was released in the Apple app store in September 2011 as the first from the *sitsim* family. There has been a gradual increase in functionality from the first release, but functionality has also been tailored to fit the specific topic for each and every *sitsim* that has been made. (Liestøl, 2011c)

3.4 Place oriented design

The last few years have seen a change in the landscape of interaction design. There has been a renewed concern about how we relate interactive technology and place. These changes have mainly been driven by development in mobile and ubiquitous computing, in technology as well as use. The strong proliferation of wireless infrastructures and networks provides increased connectivity. This is paired with increased computing power in a growing range of handheld devices. Concurrently the use of information and communication technology is changing, especially for mobile devices, e.g. commercially available LBS's are aiding the user in finding objects or people in proximity, navigating to a target, based on the user's current geographical position. (Messeter, 2009 p. 4) Providing new services to users of all kinds through applications based on LBS is an attempt to introduce new and exciting features and functionality based on interactivity.

The commercial potential is obvious in the sense that connecting a person's location with other personal details enables companies to communicate more intuitively with consumers. Rewards for checking in at places or coupons based on location are new ways of marketing. Devices will increasingly possess the ability to identify the users' immediate vicinity, object recognition services and Near Field Communication (NFC) payment (pay with your mobile phone) will give us new areas of use. (Heitzman, 2011)

In disciplines like architecture and urban planning the social, cultural and material aspects of the human environment have been an important part of design but not in interaction design[7]. As a result of the mobile development Messeter claims it makes sense to start designing interactive digital systems and services for specific places as he introduces the term *place specific computing (PSC).*(Messeter, 2009 p. 2) The concepts of the terms place and space have been a subject of debate, so to understand why there is a need for place specific computing we need to understand the terms place and space.

Space in this context, refers to structural, geometrical qualities of a physical environment. Space is extremely important in the aspect of how interactive systems operate. There are different types of spaces. Your computer desktop is a space, the wall on your Facebook is a space and the virtual world in a videogame is a space. All of these spaces have certain common elements. Within a space, there can only be one object at any given point in space and they tend to stay where they are put. Space defines distance, as things can be close together or far apart within the space. The reason why we use space as an organizing principle in software design is not so difficult to understand. Space is fundamental in the way humans think. It is part of our everyday experiences and how we organize our lives. We all share the same organization of the world, where "down" is towards the center of the earth and "up" is towards the sky, and we also understand "front" and "back" and what this implies for our field-of-view. Our common orientation to the physical world is an invaluable resource in presenting and interpreting activity and behavior. Since we know that the world is physically

[7] Interaction design is design with digital materials, shaping interactive digital systems, services and products with a particular focus on users and use experience. "MESSETER, J. 2009. Place-Specific Computing: A Place-centric Perspective for Digital Designs. International Journal of Design, Vol 3.

structured for others in just the same way as it is for ourselves, we can use this understanding to orient our own behavior for other people's use (Harrison and Dourish, 1996 p. 2).

> "Space" is largely concerned with physical properties (or metaphorical physical properties). It concerns how people and artifacts are configured in a setting; how far apart they are, how they interfere with lines of sight, how actions fall off at a distance, and so on. By configuring the space in different ways, different kinds of behaviors can be supported. (Dourish, 2001:89)

The distinction between space and place can be described as the distinction between the physical and the social. Space is not enough to describe the different kinds of behavior that emerge in different settings. Two similar settings with the same physical configurations and arrangements can cause different types of interaction. For example an academic conference can look similar to a concert, they can be held in a similar type of room, on a stage and with a big crowd, but behave very differently in these two settings. This type of behavior is determined by social norms, not by physical constraints. That is why we say space refers to the physical organization of the environment, while place refers to the way that social understandings convey an appropriate behavior framing for an environment. (Dourish, 2001:89f) In other words, the way we manage collaborative activity is not rooted in space at all, but in a mutual cultural understanding of behavior and action.

> Place is space with invested understandings of behavioral appropriateness and cultural expectations: "space is the opportunity; place is the understood reality". (Harrison & Dourish in Messeter, 2009 p. 3)

In his paper about place specific computing (PSC) Messeter introduces, a complementary perspective for interaction design, one that reaches beyond the user-centric notion of place in location based systems. Instead of focusing on the needs of user groups, the focus is on the local, social, cultural and material resources and conditions of the place.

> As a genre of interaction design place-specific computing may be described as computing in which the designed functionality of systems and services, as well as information provided by these systems and services, are inherently grounded in and emanating from the social and cultural practices of a particular place, and account for the structuring conditions of place – social and cultural as well as material. Systems and services are thereby designed to cater to the people that, temporarily or regularly, visit or dwell in a particular place. (Messeter, 2009 p. 7)

The focus of PSC is to design for the place instead of designing for a target group. Consequently, services, users and needs also change over time as a place develops. Views from human geography on how to define space and place has influenced PSC strongly. Human geography has had limited influence on the understanding of place in interaction design research up until now. Only a few examples as in Luigina Ciolfi's "Re-Tracing the

Past” (Ciolfi, 2004) (the interactive museum installation) and Björgvinson’s research project “REcult”[8] (Björgvinsson, 2007) have successfully applied such a perspective. Ciolfini was very much influenced by the Chinese-U.S. geographer Yi-Fu Tuan, one of the main proponents of a phenomenological approach in geography when doing this work. According to Tuan space refers to an abstract geometrical extension and location. Place describes how people experience being in the world and the feelings, meanings and memories they invest in that physical location. Place has, of course, an existential significance as places are entities which "incarnate the experience and aspirations of people"(Tuan in Ciolfi, 2004 p. 19) Today in human geography, place is regarded as a determinate part of the world and how it is influenced and developed through “rich and complicated interplay between people and the environment.” (Cresswell, 2004 p.11) A renewed interest for phenomenology has also given focus to embodied interaction in interaction design, emphasizing the qualities of our participation in immediate surroundings. (Dourish, 2001) This embodiment is about establishing meaning. Embodied interaction lets us engage with technology the way we interact in real life as it opens up for the development of meaning in computer interaction. Dourish suggests that ubiquitous computing is about focusing on ‘place’ rather than ‘space,’ since place is socially meaningful. Context is continually produced and negotiated through our everyday actions. (Messeter, 2009 p. 10)

> Meaning arises in the course of action. This is to say that meaning is not inherent in the technology, and therefore not determined by the designer. Rather, meaning emerges through the encounter with technology, making it open for various appropriations and adaptations as it is incorporated into a community of practice. (Messeter, 2009 p. 10)

Actions are neither determined by structures around us or completely by free will. Material structures as well as rules, laws and social expectations provide constraints. In this way, places are never finished entities, but in constant change or being in process. (Cresswell, 2004)

Place specific computing can operate on many different scales. But what defines the boundaries of the place? The scale isn’t determined by the designer but by the social and material conditions of the place. So if place specific services are developed from local resources, how local are local? According to Tuan a place can be from the corner of a room to the whole of the earth. This unbound definition of space is problematic for PSC. (Tuan in Messeter, 2009 p. 17)

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[8] a research on how self-produced rich media can facilitate the sharing of meaning in healthcare

> Places maintain their identity through shared perceptions of their specific culture as part of their on-going social construction. The scale of place, and the scope of place-specific computing concepts, is therefore strongly rooted in identity. Consequently, designing place-specific computing requires an understanding of identity. (Messeter, 2009 p. 18)

The main concern for PSC is to enhance places through digital media and technology that are grounded in specific socio-material circumstances offered by a place. PSC becomes part of the continuous construction and re-construction of place. The design approach should not only be grounded in the studies of place and its social, cultural and material conditions, but also the dynamics of the place. By adding to the potential to shift meanings and interactions, places can develop in new directions. In short, PSC is about designing in place. (Messeter, 2009 pp. 18-19)

> In essence, PSC addresses the shaping of interactions between people and place-specific resources, mediated by digital systems and services, and connected to global socio-technical networks. PSC is introduced with the intention of clarifying the relationship between interactive digital systems and services and the concept of place for interaction design, informed by research in human geography…
>
> … It merely suggests that the range of users is determined by the place for the design, rather than being defined as a target group disconnected from place. (Messeter, 2009 pp. 18-19)

As place is significant in the context of *sitsim*, PSC can be a sensible approach for interaction design. *Sitsim* applications are built for a specific geographical spot somewhere in the world. They are designed to convey the cultural meaning of a place, to present information of historical value and give insight into events that took place there. *Sitsim* attempts to augment the experience people have of a certain location, in giving them the opportunity to see objects that are no longer there, and enhancing the perspective of a structure or phenomenon. *Sitsims* can be described much in the same way as Azuma describes the possibilities of AR:

> AR might aid general visualization tasks as well. An architect with a see-through HMD might be able to look out a window and see how a proposed new skyscraper would change her view. If a database containing information about a building's structure was available, AR might give architects "X-ray vision" inside a building, showing where the pipes, electric lines, and structural supports are inside the walls [Feiner95].(Azuma, 1997 p. 7)

Such functionality can give the user new perspectives to a specific place and thereby also new types of experiences. *Sitsim* does not only give such a perspective but it also gives a first person view of that phenomenon as well.

Studies have shown that immersion into digital environments can give the user multiple perspectives. With funding from the National Science Foundation, the Project ScienceSpace research team did studies on sensory immersion. They discovered that exocentric and egocentric perspectives offer different learning possibilities. Being able to change a user's perspective or frame of reference can be a powerful tool in helping someone understand a place or a complex phenomenon. Typically this is done by shifting between an exocentric and egocentric frame of reference. The exocentric frame of reference provides a view of an object, space or phenomenon from the outside, while an egocentric frame of reference provides a view from within the object, space or phenomenon. (Fig. 26) (Dede, 2009 p. 66)

A major advantage of egocentric perspectives is that they enable participants' actional immersion and motivation through embodied, concrete learning, whereas exocentric perspectives foster more abstract, symbolic insights gained from distancing oneself from the context (seeing the forest rather than the trees). (Dede, 2009 p. 66)

In HTT the immersion into the 3D world is evident. The perspective of the user is 1.7 meters above ground, much like the average human eye height. Through the perspective the user has an egocentric perspective of the world much like that which is illustrated in. (Fig 26) The egocentric view will simulate being at the arena but in a different year. This perspective is important to understand the size, space and objects of Holmenkollen.

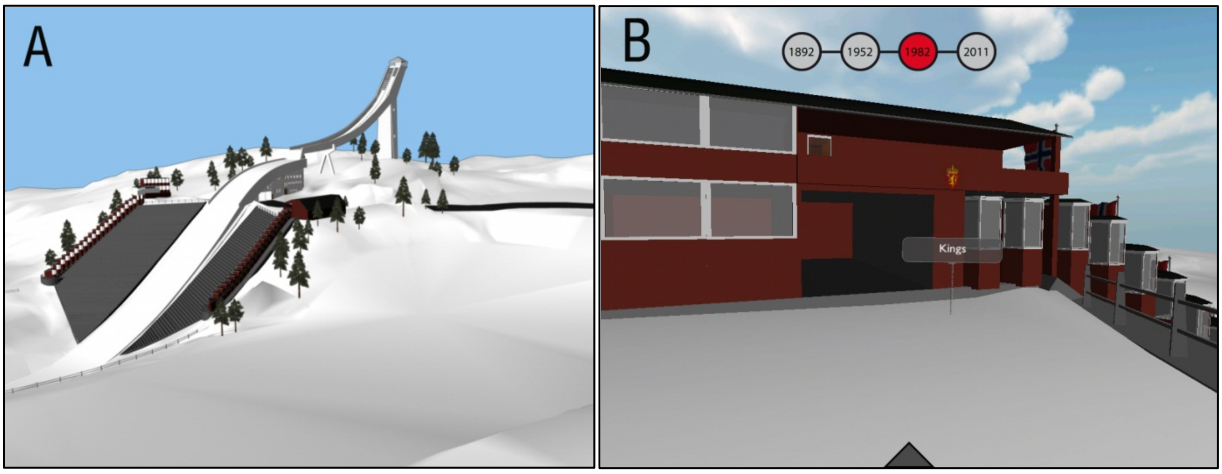


Figure 27: A) Exocentric view of HTT - 1982 **B) Egocentric view of HTT – 1982**

4 Methodology and testing

In the following chapter will cover the methodology and the field tests done in the HTT project. The project had the total of eleven test days. The first half of these test days where dedicated pre-testing and adjustments of positioning and content placement. The second half was purely user testing. I will provide a thorough description of the ethnographic approach I have used to conduct these tests.

4.1 Early test phases and development

A development process of nearly 9 months is an integral part of the data gathering. This process is strongly linked to my understanding of the HTT and forms the basis of the application that the users experience. During the development of HTT I conducted three separate rounds of testing. In the creative phase the main objective of the testing was to find out if Holmenkollen was at all suited for a *sitsim* application. There are some key factors that need to be in place for a *sitsim* to be able to function up to expectation, e.g. GPS coverage, 3G coverage or WIFI internet, and whether movement around the object is possible. The second round of testing I conducted in collaboration with the CodeGrind AB's programmer who is working for the INVENTIO-project. Each new version of the HTT had to be taken to Holmenkollen to be tested thoroughly to check if positioning and basic functionality was working as planned. The third round was end-user testing in the Holmenkollen arena with a finished prototype. To get diverse feedback end-users with different backgrounds were used to test the application.[9] The four groups chosen included one employee at Holmenkollen, Klaus Kromann, the operations manager working for the ski association, a group of tourists randomly picked at the arena, a group of media students from the University of Oslo and one group of people with a broad technical background (one of them a student from the Department of Informatics). I was aware that choosing acquaintances and colleagues as informants might bias their replies. On one hand, an informant's relationship to the researcher can influence the answers they give in a negative manner as they might subconsciously want to please and praise the researcher's work. It can also make them less focused while carrying out the test. On the other hand it can make them speak more freely,

[9] Because completing the app took more time than expected the test group was not optimal. Time limitations forced me to choose acquaintances for parts of the testing.

resulting in better feedback. In addition I would have knowledge about their background and skills. I made it plain to them before the test that they must give me honest and straightforward answers to the questions emphasizing that critique was useful in improving the application for the future. I also sought to counteract biased answers by asking questions in a manner that prevented a positive/negative response giving them instead questions that required them to elaborate and reflect on the functionality and the experience. Totally I had eleven test days in the Holmenkollen ski arena. This chapter will describe in detail how these tests were carried out.

4.1.1 Movement and Coverage

As mentioned, Holmenkollen is situated north of Oslo almost on the top of the ridge that surrounds the city. There are few obstacles to block signals to the iPad. Both GPS and 3G signals are good except when the user moves underneath the jump of the ski jumping hill. As the construction is made of concrete and steel the signal strength, especially from the GPS satellites, get notably weaker here and makes the movement inside the application uneven, and with some delay. The purpose of the first test was to get technical information about the area. Signal strength is crucial when making a *sitsim* work up to expectations. To measure the GPS signal I used an iPhone application called "GPS Status" acquired at the App Store[10] which gives simple but accurate information about GPS coverage and location. It gives data like GPS signal strength; from none to very good, horizontal accuracy, vertical accuracy, speed, course, latitude, longitude and time.

4.1.2 Global Positioning System

GPS satellites transmit signals to equipment on the ground. A GPS receiver needs a clear view of the sky so the technology is mainly used outside and does not work well close to tall constructions or in forests. The receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite transmits messages that contain information about the time when the message was sent, precise orbital information and the general system health and rough orbits of all GPS satellites. The receiver uses the message to

[10] GPS Status was downloaded from App Store within the iTunes application. http://itunes.apple.com/us/app/gps-status/id378085995?mt=8

determine the transit time of each message and computes the distance to each satellite. These distances along with the satellites' locations are used with the possible aid of trilateration (the process of determining absolute or relative locations of points by measurement of distances) to compute the position of the receiver. This position is then displayed as movement on a map, in longitude and latitude, or as in this *sitsim* movement in a 3D world. (Wikipedia.com, 2011a, Pellerin, 2006)

During this first test I used the iPhone 3GS which has a slightly weaker GPS receiver than the iPhone 4 and iPad 2, but still giving good indication on how the conditions were at Holmenkollen. To register my data I used photographs of the area with graphics to display the signal strength. The stars in the photo also represent the movement patterns around the arena where the user can walk around freely with the application. (Fig. 27) These movement patterns were later reviewed to ensure that they matched the earlier hills and terrain. As this is a frequently visited tourist spot, not surprisingly 3G coverage is good. It follows in theory, that Internet speed would also is good. But this is only in theory. Base stations are a shared resource, and performance depends on how many clients are connected simultaneously This was quite noticeable while testing. The WIFI coverage was more of a surprise to me as it provided a good and stable signal all over the arena. Only under the jump, as with the GPS and the 3G, the coverage was poor. Since WIFI has a much better bandwidth than 3G, this opened up for video streaming inside the application.

Figure 28: GPS coverage, early development

4.1.3 Testing 3D and positioning

The first usable implementation of the application was done in September 2011 and on-location testing was done shortly after. Difficulties regarding positioning caused further tweaking and a new default origin[11] in the model was set. After two more test runs locative functionality was up to standard. The second task that needed sorting was placement of content within the application. The links had to be placed in the terrain within Unity itself. For the CodeGrind programmer to understand where to place these links he needed instructions. These instructions were made from renderings in Maya edited in Photoshop. (Fig. 28) Each of the three 3D models had unique placement.

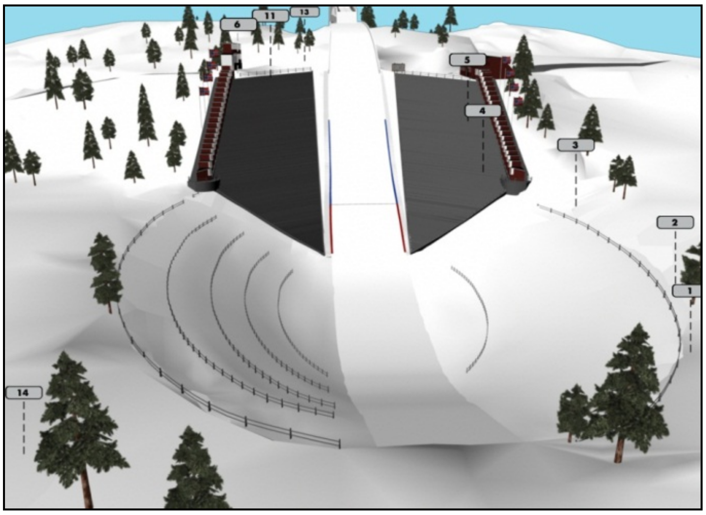


Figure 29: Link placement

4.1.4 User tests

The user tests were conducted over a period of ten days in the last week of October. At that time of year the weather was getting cold and wet. One test had to be cancelled because of heavy rain. Another test was interrupted as the users were struggling with the response of the screen because of cold fingers. Touch screens are an electronic visual display that responds to touch of a finger or a hand on the screen itself. Touchscreens can also sense the touch of passive objects like the use of a stylus[12]. There are two main types of touch screens available on the market: resistive and capacitive screens. A resistive screen is composed from a sandwich of layers where the cover sheet consists of a hard outer surface with a coated inner side. The two most important layers are two thin films of conductive material (usually Indium Tin Oxide or ITO) separated by a narrow gap. When the finger or stylus touches down on the screen, these two layers are pressed together and connect at that exact point. This causes a

[11] Center point of the application, where longitude and latitude is set from the real world which correspond with the terrain in the virtual world

[12] Stylus: Is used as a pointing device on touchscreens. It is similar to a pen in shape but can have a conductive tip if made for capacitive screens. STYLUSCENTRAL.COM. 2011. What is a Stylus? [Online]. StylusCentral.com. Available: http://tinyurl.com/6wf99m3 [Accessed].

change in the electrical current and the registration of the touch is sent to the controller for processing. The other type of screens which is to be found in the iPad 2 is called capacitive screens. They come in two different types, surface and projected where the latter is the one used for smart phones and tablets. The construction of the screen is like the resistive screen, several layers on top of each other like a sandwich. The touch screen panel consists of two spaced insulators such as glass which is coated with a transparent conductor like ITO. Depending on the particular screen, the ITO layer may be a uniform coat, a grid, or parallel stripes running at right angles on the two layers. As the body is also an electric conductor, touching the surface of the screen causes changes in the local electrostatic field. The system which constantly monitors each tiny capacitor discovers exactly where the finger touched the screen. Unlike the resistive screen it can also register touch of multiple fingers increasing the range of functionality. A well-known disadvantage for this type of screen is its poor usability in cold weather conditions. It is not possible to use a capacitive touchscreen through most

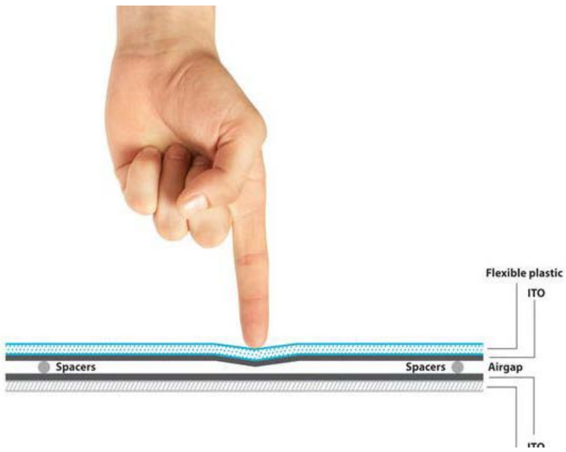
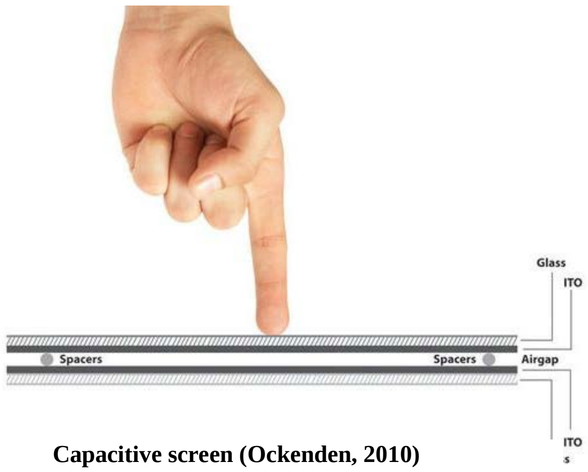


Figure 30: Resistive screen (Ockenden, 2010)



Capacitive screen (Ockenden, 2010)

types of electrically insulating material, such as gloves. One requires a special capacitive stylus, or specially made touch screen gloves.[13] (Ockenden, 2010, Wikipedia.com, 2011c) Because of the issues regarding cold fingers and low response on the screen I made an effort to get hold of touchscreen gloves in Oslo. Touch screen gloves were at that time quite hard to get from stores and it takes days to get them if you order online. As I needed them quickly I had to make them myself. As conductive thread[14] or conductive pins[15] is also hard to come

[13] Touchscreen gloves

[14] Conductive thread can carry current for power and signal, like from your finger to the touchscreen. It is soft so it doesn't scratch the glass. SPARKFUN.COM. 2011. Conductive thread [Online]. Sparkfun Electronics. Available: http://www.sparkfun.com/products/8544 [Accessed].

by, I made two different glove models for testing. The first pair of gloves were without tips on index finger and thumb on both hands. The gloves keep the hand warm and a warm finger works better on a capacitive screen. The second pair of gloves were painted with conductive silver paint on the inside and outside of the index finger and thumb on both hands. The silver paint is a mixture of car paint and silver (18%) used mainly by car mechanics to fix back window heating. The paint created a conductive surface on the fingertip that connected with the screen. The gloves worked well, but gave of a little smear on the screen. During the last three rounds of testing the gloves without fingertips were used, with the silver tipped ones as backup.

4.2 Methodological approach and user testing

A *sitsim* has strict frames of design. On the other hand it is an application in development with plenty of room for changes. My approach is an inductive one, also called a bottom up approach.

> In inductive reasoning, we begin with specific observations and measures, begin to detect patterns and regularities, formulate some tentative hypotheses that we can explore, and finally end up developing some general conclusions or theories. (Trochim, 2006)

The data is gathered through ethnographic qualitative means, in addition to my own reflections and experiences throughout designing and testing HTT. Ethnography has a long tradition in design as a method for understanding work practices and technological artifacts in use, or to include user perspectives in technology design. The aim of an ethnographic study is to inform the designers about the observations and the analysis. Ethnographic methods have become both a means to facilitate communication and a vehicle for producing information relevant for the design of new products. Ethnography has the potential of providing a context where there is a mutual understanding between the users, designers and ethnographers. They can together explore a practice, contribute with their knowledge and create a common ground in order to enable the design. (Stuedahl et al., 2010 p. 107)

> Ethnography has become popular within the interaction design because it allows designers to obtain a detailed and nuanced understanding of people's behavior and the use of technology that cannot be obtained by other methods of data gathering. (Sharp et al., 2011 p. 252)

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[15] Conductive pins are made with special conductive silicone TONIC, T. 2011. Digits Conductive Pins for Gloves [Online]. Touch Tonic. Available: http://www.touchtonic.com/Digits-Conductive-Pins-for-Gloves.html [Accessed].

My choice of method was based on my experience from research on the *sitsim Forum Iuium*[16], research done by the INVENTIO-project, method used on similar projects[17] and on the basis of preferred techniques used in Human-computer interaction (HCI)[18]. (Sharp et al., 2011) The main focus in HCI is to develop good interfaces or good design which is somewhat a little different from mine. The focus in HCI emphasizes the need for a user-centered approach to software development. When designing HTT I was reluctant to follow this rigidly. User-centered design relies on user involvement throughout the design process, leading to a solution that users will find useful and want to use. To achieve that, you first need to have a clear understanding of your users, grouped into a prioritized set of user groups whose needs can be thought of individually. There are three principles that are now accepted as the basis for the user-centered approach. *Early focus on users and tasks*: This requires observing the users to understand who you are dealing with and understanding their normal tasks so that you can involve them in the design process. *Empirical measurements*: in early and later part of development the user's reactions and performances are observed, recorded and analyzed. *Iterative design*: Build a prototype, test it, fix it and produce another version. Then test it again to see if it is fixed. These cycles of design-test-measure-redesign are repeated as often as necessary. (Sharp et al., 2011 p. 326) The involvement of users in the design process implies the acknowledgement that good design is reached through consensus. In the design phase I have chosen to focus more on place than on the user.

> Place-specific computing is inherently grounded in and emanating from the social and cultural practices of a particular place, and account for the structuring conditions of place – social and cultural as well as material. Systems and services are thereby designed to cater to the people that, temporarily or regularly, visit or dwell in a particular place. (Messeter, 2009 p. 7)

Finding a typical user or visitor in Holmenkollen is difficult. Holmenkollen has a range of users from tourists who has read about it in a guide book, school classes, and ski interested people. Visitors are young, old, male, female, interested in sports or not, interested in culture or not.

[16] Forum Iulium: ORKELBOG, V. F. 2010. SITUATED SIMULATION AS A LEARNING TOOL – EXPERIENCING FORUM IULIUM WITH THE IPHONE. IADIS International Conference on Cognition and Exploratory Learning in Digital Age. Timisoara, Romainia: IADIS Press.

[17] Crags: STAFF, M. W. 2011. Designing Climbing Guides for Mobile Devices. Masters Degree in Media and communication, University of Oslo.

[18] HCI: understanding the interplay between the technology, people and the society. We use this knowledge to develop computer systems SINTEF. 2011. Human-Computer Interaction (HCI) [Online]. Sintef. Available: http://www.sintef.no/hci [Accessed].

We haven’t spent 1.8 billion kroner on this hill so that Romøren and the other ski jumpers could have a new hill to play in. This is about advertising Norway, this is how we want to present our self to the world, where Nansen himself wishes you welcome. (Værvågen, 2011)

It is obvious that Holmenkollen appears to be something more than only a ski jumping hill to Norwegians. Holmenkollen is a ski arena, a tourist attraction, a viewpoint over Oslo and now also an architectural monument. In the HTT application the most important perspective is to be true to Holmenkollen. Because of this way I wanted to steer away from the typical user centered design. *“the range of users is determined by the place we design for, rather than being defined as a target group disconnected from place.” (Messeter, 2009 p. 7)*

The testing of the application could be described as evaluative ethnography, a method to verify or validate a set of already formulated design decisions. *“Evaluative ethnography involves an evaluation of design that has already been completed”* (Stuedahl et al., 2010 p. 109) This use of ethnography could be developed into a systematic means of monitoring how a system is functioning and could also be useful in “tweaking” existing systems, and for informing the designers of the next generation of systems. (Hughes et al., 1994 pp. 434-435)

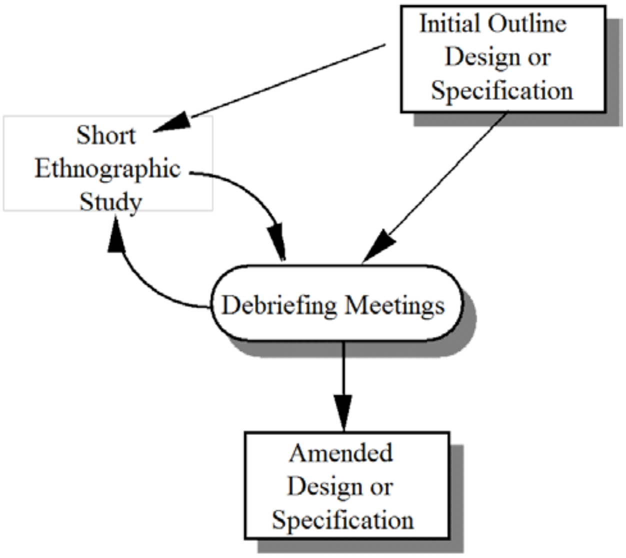

Figure 31: Evaluative ethnography (Hughes et al., 1994)

The HTT saw no involvement of test-users until the prototype was completed. During the developing phase the application was tested by me alone. These tests focused on: area testing, basic functionality and positioning. Such tests are better done alone as they often last no longer than five to fifteen minutes and don’t need multiple testers to conclude if the application is working as planned. Of course there have been several versions of *sitsim* application earlier on, and they have been tested by users on location. One could therefore assert that navigation and functionality have been tested before. (Liestøl et al., 2011) This aside, evaluation and analysis of HTT are done on the basis of a reflective approach. Testing gives the designer an opportunity to interpret the application. Harold Nelson and Erik Stolterman state that there is a need for interpretation in design.

Interpretation, as a part of the design process, serves the same purpose as evidence and proof does in science. Interpretation is part of our attempt to grasp the conditions and context that exist and will set the stage for our ideas and new design. (Stuedahl et al., 2010 p. 106)

The evaluation is done in the ethnographic tradition. The project used four main methods of data collection in the test phase to achieve methodological triangulation: observation, survey (questionnaire), focus groups and interview. (Sharp et al., 2011 p. 225)

4.2.1 Observation

Observation conducted in later parts of development, e.g. in evaluation, may be used to investigate how well the prototype supports the tasks and goals. (Sharp et al., 2011 p. 247)

Observation was done through all the four test days. After a short introduction to the application the test subjects were sent off to explore and to use the application freely while I moved into background watching their interaction and movement in the arena. During the observation I looked for general use, technical problems, navigation and other issues connected to usability and functionality. Notes and pictures were taken for documentation, but kept encrypted on the hard drive for anonymity.

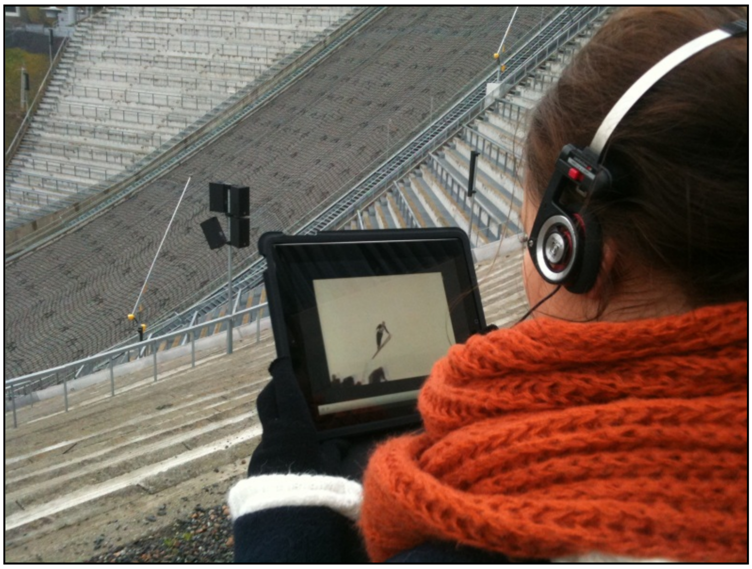

Figure 32: User-test on location

4.2.2 Survey

Sharpe et al. describes making a decision between interviewing or using a questionnaire depends on the motivation of the respondents to answer the question. If you think the motivation is high enough to complete a questionnaire without anyone else present, a questionnaire will be appropriate. (Sharp et al., 2011 p. 238) I drew up a questionnaire to cover the most important questions. Since I was planning a brief focus group discussion I knew that I would have the opportunity to ask follow-up questions if the questionnaire didn't give me adequate answers. The questionnaire was supposed to be the same one for all three test rounds. What I didn't take into consideration at first was how much time it is possible to demand from tourists picked up randomly on location. It resulted in one shorter and less qualitative questionnaire for the tourist group as a compromise. There were fifteen questions in *Likert scale*[19], with a gradation from one to six. As these testers were in a hurry they never asked me questions about the questionnaire even if I was standing only a few meters away. One of my questions was not properly addressed, something that resulted in useless response to one specific question.

Clearly worded questions are particularly important when there is no researcher present to encourage the respondent and to resolve any ambiguities or misunderstandings. (Sharp et al., 2011 p. 238)

This was a valuable lesson learned before the next rounds of testing.

This test also made me aware of some problem areas that needed to be solved in order to improve the questionnaire. The next two rounds had no time limitations and the questionnaires had a much more qualitative approach than the first test. Many of the questions where designed as questions from a structured interview and gave more supplementary answers. The questionnaire contained twenty six questions. Ten of these were based on the *Likert scale* while the other sixteen had qualitative questions requiring the testers to elaborate on their experiences.

Figure 33: Questionnaire and focus groups

[19] Likert scales are used for measuring opinions, attitudes and beliefs, and consequently they are widely used for evaluating user satisfaction with products. SHARP, H., ROGERS, Y. & PREECE, J. 2011. Interaction design: beyond human-computer interaction, Chichester, Wiley.

4.2.3 Focus groups

After completing the testing and the questionnaires the media students and people with technological background were gathered into two focus groups. These groups contained four and three people. These focus groups were conducted as small group conversations around a table, and the conversation flowed freely with me as an observer, only asking open ended questions to keep the conversation going. The main purpose of these focus groups was to get a more thorough understanding of their experiences using the HTT. As some testers might not have the required vocabulary to express their thoughts, it can often be helpful to speak openly in a group to loosen up the conversation and help them to express their feelings. A focus group can allow for diverse or sensitive issues to be raised that might otherwise be missed. Focus groups aim to enable people to put forward their own opinions in a supportive environment. (Sharp et al., 2011 p. 232)

4.2.4 Interview

I conducted one interview with the operations manager in Holmenkollen. The interview was a semi-structured one held in a lunch room. The setting was informal with people going in and out of the room. The questions were based on the survey and I had a basic script for guidance.

4.3 User-tests

4.3.1 Tourists

The user test started with four tourists randomly picked at the ski museum in Holmenkollen. As tourists often are in a group, in a hurry for different reasons, or just skeptical to people asking them for things, the whole sequence was planned as a 20-30 minute intensive test. Inside that time they agreed to participate in a survey where they would answer 15 questions in an anonymous questionnaire. The questionnaire included only multiple choice questions for more effective implementation. After a short introduction I sent them off into the arena, with me in the background assisting them when needed and observing.

4.3.2 Media students

The second test group was made up of 4 master students from the department of media and communication at the University of Oslo. The test lasted for almost 2 ½ hours and had a more extensive questionnaire containing questions where the users needed to reflect and elaborate on their experience. Also here I gave a quick introduction to the application before they started exploring the arena. They moved from down by the landing area, around it, up the stands on the right side, under the jump over to the left side of the stands before they ended the test by the museum underneath the inrun. After testing the application the whole group moved into the café where they started answering the questionnaire. There were a total of 25 questions and one third of the questions were multiple-choice. The session ended with a group discussion where the participants discussed their experiences.

4.3.3 Technological group

Three people took part in the third test round. To get more technical feedback on functionality, this group was composed of two students with a background from ICT and a journalist with technical background. This group participated in the same test as the media students in round two.

4.3.4 Holmenkollen employee

The last and final test was conducted with the operations manager in Holmenkollen, Klaus Kromann. He was chosen because of his vast knowledge and experience. He has been working in Holmenkollen for a long time and has in-depth knowledge of the construction of the new hill as well as of the former hill. He has also a sincere interest in Holmenkollen and ski jumping. He had a more professional angle to the application than the other testers. His test was similar to the second and the third test group, but ended in an hour’s interview. This test was probably the longest one as his interest for details far surpassed the other testers.

Figure 34: Holmenkollen employee testing in Holmenkollen

5 Findings

The analysis is divided into chapters including Location Based Services, perspective, Augmented Reality, Place Specific Computing and limitations, bugs and further development. The analysis is based on the theoretical background, my thoughts and experiences from the development phase and the response collected through questionnaires, focus groups and the interview from the different test groups.

5.1 Location-Based Services

There has been an important change in how we interact with computers throughout the last decade. Earlier we were restricted to using a keyboard and a pointing device, now the interface allows us to interact or create movement in other ways. Tablet computers, smartphones and gaming consoles are leading the way, but there are also several other devices available. Similar technology may have been available for a long time as seen in VR solutions and early tablets, but only during the last five to eight years has technological development and convergence caused fully functional commercial products. Human movements are now being tracked and transferred onto the screen. The technology can make computer application more user-friendly but can also have health benefits as a growing part of our young population is less active than before. In gaming, high detailed motion sensing and location tracking makes it possible to simulate sports and activities quite accurately. The *Kinect for Xbox* has for example a completely hands-free control using a sensor device that has an infrared projector, camera and a microchip that interpret specific gestures in three dimensions.(Xbox.com, 2012) In smartphones and on tablet computers motion sensing and location tracking are more basic as all sensors are placed internally. Only motions of the device itself are monitored, making it better suited for simple game controls or navigation used for exploring VE or AR spaces. This functionality is what is used in the HTT to explore Holmenkollen. As location awareness is the backbone of any *sitsim* I have focused on the experiences gained through the testing of HTT.

5.1.1 Movement and navigation

Much like the traditional AR solution, *sitsim* is a location-aware LBS service and uses its technical abilities to change the perspective. GPS, accelerometer, magnetometer, and gyroscope track movements done by the user. The functionality of the LBS is similar to what you see in a car navigation system where location information is provided on request and the driver gets a real-time navigation service. The GPS device calculates the cars position by connecting to numerous satellites and as soon as the car starts moving the positional change is recorded. Combined with the map installed on the device, directional information is provided to the driver. In HTT the iPad connects to GPS satellites just like the car navigation and the users physical movements are tracked. In addition, directional movements are also registered as the user turns around changing the perspective. The iPad records the positional and directional movements and changes the perspective on the screen in real-time to match the user's real perspective of the world.

Navigating inside the HTT there are four different levels. The first level is basic movement inside the application which is more or less like natural movement described above, the second level is changing between the different hills or views using the string of circles in the top part of the screen, the third is interaction with the content (the links in the terrain) and the fourth is navigation in the camera-view (2011) using the dock menu. The eleven test subjects in the first three test rounds gave the navigation a positive review, but there were some negative remarks.

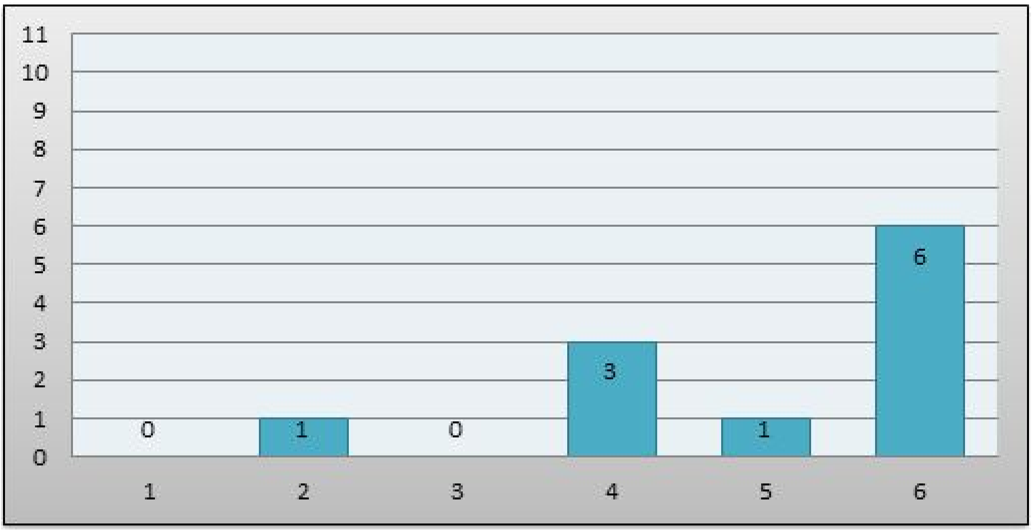

Figure 35: How is it to navigate in the application HTT? (1 extremely difficult – 6 very easy)

Some negative response was directly connected to GPS accuracy. Movement around the arena flows well as long as the GPS signal is strong, but there are a few places where the signal strength is unstable. In those positions, especially around the take-off, the signal is weaker as the steel and concrete construction of the ski jumping hill shields the GPS signal from reaching the device. The user's position will thereby be a little off and the movement becomes jagged. The users replied in the questionnaire accordingly;

"The GPS changed the view in a strange way sometimes; maybe do something to keep it steadier. The view jumped back and forth" (Orkelbog, 2011b)

"GPS accuracy – WIFI-connection- problems with level/height in the different views" (Orkelbog, 2011b)

"Poor control at times – being left in the hands of a GPS" (Orkelbog, 2011b)

The GPS inaccuracies made it difficult at times to interact with content as the "virtual camera" moved back and forth rapidly making it hard to tap the link. The GPS issues are difficult to improve. Luckily there are only a few positions around the arena that are actually affected by these limitations. One way to improve the experience is to place less interactive content in the problem areas. There were also positive comments on the GPS navigation. Especially Kromann who spent more time than the rest of the testers studying detail in the 3D models commented;

"If you want to pass through a door or a tunnel it is important that the GPS is accurate. In some parts of Holmenkollen there are some objects that have been there for a long time, like the jump building which is the only remaining part of the old hill. When I walked around that building on the test, the 3D model of the 1982 hill matched very well with reality in both position and size" (Orkelbog, 2011a)

The menu controlling the different views was appreciated by the users. They switched between the different years many times during the test and seemed to enjoy comparing the different hills. Several of the user's describe this feature as their favorite part of the HTT.

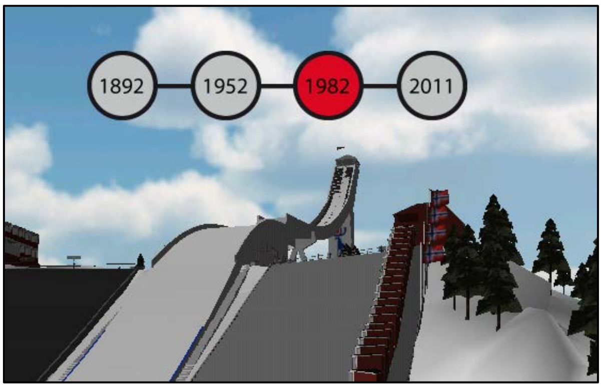

Figure 36: Menu to change view

"The possibility to see the Holmenkollen in different times" (Orkelbog, 2011b)

"Travel back in time and see today vs. then" (Orkelbog, 2011b)

To develop this feature further it might be an idea to add a loading bar as the application changes from one view to the next. In today's prototype it seems like the screen freezes, as the loading of a new scene takes a few seconds to complete. While I was observing the test it was evident in the beginning that some testers got impatient and thought that the application had stopped working.

The links were a problem during testing. Some found them hard to activate for three different reasons. Either they had cold fingers, were too far away or had an awkward angle to the *link.* Some even wanted them to have a different look; *"Balloons" (links) could be easier to see; different colors, size or shape."* The fact is that the links can be a bit hard to interact with, especially if the user doesn't face the link dead on.

Positioning the links was a big challenge during development of the HTT. There are several issues that need to be highlighted to clarify why. First of all there are four different views that all need content. The most important issue has been to decide where to place the links in the terrain. Some of the links have a direct connection to a certain object in the 3D world and will therefore have a natural position. One example would be the royal grand stand. This royal grand stand will not necessarily have the same position in all the hills, but then it is up to the user to explore the environment if they wish to find out where it was situated. Other types of content do not have the same direct connection to an object within the 3D world, which makes it more difficult to find a suitable place for the link. An example of this would be a video compilation of the top three competitors in the Olympics in 1952. There is no natural place for this link in the 1952 hill; instead one has to find a logically suited place for it. In this case I would say that somewhere in the stands could be a suitable place. If there are too many links with no obvious position the application will have reduced usability and acceptance. There is another challenge regarding placement of the links. As the user starts the application and enters a certain view she will start exploring the VE. On the walk over to a link she might pass links in another view that she doesn't see at that time. After a while she will change the view and probably realize that she has missed certain content. The question is; will the user walk all the way back to see what she has missed, or just push on? And will it change the way the user navigates in general?

"A little, the hills changed and that was exciting. Checked out the different years and the info about those years. It changed the way I navigated as I compared and backtracked in the terrain." (Orkelbog, 2011b)

Some replied it made them change between the views more frequently to get as much information as possible. Others replied that it didn't change how they navigated at all. Even if many of them enjoyed exploring the VE, these issues made them realize that the application was somewhat unorganized. When asked what could be improved in HTT many wished for the same things;

"I felt that some of the "balloons" were placed a little random. For me it was ok because I was already there at the time, but I think I probably wouldn't see all of them if I was sightseeing by myself. Maybe it would be smart with a mini-map that showed all the information could have been included in a sort of intro start page in the app" (Orkelbog, 2011b)

"Could have been presented in a shared list. – It could have been the same in all years so you didn't have to change view to be sure that you didn't miss anything." (Orkelbog, 2011b)

"Birds-eye map where all links are plotted, so if you can go through the links from a stationary point" (Orkelbog, 2011b)

"Big links, better arranged or with an overview map where you can find all the links – could be a menu accessible from everywhere." (Orkelbog, 2011b)

These links (described in chapter 2), are positioned so that the user physically has to walk over to them. The links have a position in the terrain so they can only be reached from that specific location. During the development of HTT I saw a problem in this navigational setup. If a user misses several links or just want to see them again, she would probably not backtrack several hundred meters to find this content. To improve functionality I built an information sign in each of the hills (described in chapter 2). The information sign gives the user an opportunity to see all available content in the application from one position. During testing this link was frequently used, but the design was criticized. As the content database became larger than first assumed the word-cloud shape became over-complex and it didn't help much that the different views were color coded. One tester commented: *"Info web page was messy and not well arranged"*. (Orkelbog, 2011b) In a later version I would definitely reconsider the layout of this page and categorize the content differently as it looks rather unorganized.

As the amount of content increases and the 3D world's size grows the need for some sort of overview of the area and the content represented. The comments about the need for a *"world map"* are reasonable, especially as Holmenkollen is a big arena, with long and steep steps. Maybe it would be practical if the user could plan their movements in advance and finish all of the links in one area before moving on to the next.

The 2011 hill has a completely different type of navigation; a traditional list menu opens from the dock. This form of navigation breaks with the traditional perspective of a *sitsim*. This menu was appreciated by some testers for its simplicity, but it is originally a backup solution which will be discussed further in the chapter on further development. (see chapter 5.5.4)

5.2 Perspective

HTT's perspective is similar to the perspective of earlier *sitsims*' as described below by Liestøl;

> The smartphone thus serves as a point of view – a virtual camera – which provides a continually changing perspective into the 3D graphics environment. When using a situated simulation there is then approximate identity between the user's visual perspective and perception of the real physical environment, and the user's perspective in(to) the virtual environment as this is audio-visually presented by means of the phone and sitsim's interface. The relative congruity between the 'real' and the 'virtual' is obtained by allowing the camera's position, movement and orientation in the 3D environment, to be constrained by the orientation- and location technology of the smartphone: As the user moves the phone in real space the perspective inside the virtual space changes accordingly. (Liestøl, 2011a)

This perspective gives a unique possibility to see the former hills of Holmenkollen from a perspective that simulates the user being there in a time when it still existed. Like traveling in time the user can re-live old construction to better understand shape, size and the surroundings. By adding the right sounds and visual design, atmosphere and social circumstances can be recreated. When a tourist travel to Rome to experience ancient Roman times they always wonder what it really was like being there.

Chris Dede's research shows that immersion into digital environments can give multiple perspectives and that the exocentric and egocentric perspective have different strengths for learning. HTT has an egocentric perspective, seen from the eyes of a person, 1.7 meters above ground, within the 3D world. Dede claims that this is the best possible perspective to understand a space, object or phenomenon. When people go to visit historical places, they want to re-live and understand the place and the people who were living there. People have always had an urge to travel in time and technological advances have been implemented in museums to aid people in this task. The same counts for the users of HTT. Since 1997, the Virtual World Heritage Laboratory of the University of Virginia (VWHL), the UCLA Experiential Technology Center (ETC), the Reverse Engineering (INDACO) Lab at the

Politecnico di Milano, the Ausonius Institute of the CNRS and the University of Bordeaux-3, and the University of Caen have collaborated on a project to create a digital model of ancient Rome as it appeared in 320 A.D. (romereborn.virginia.edu, 2010) In his article, Bernard Frischer, Director of the Rome Reborn Project[20], describes an observation they did after completing the 3D model of Ancient Rome that can confirm and exemplify Dede's claims about the egocentric perspective;

When you entered into the vast space of Trajan's Forum, you could see the enormous statue of the Emperor Trajan atop his column at the end of the long axis. This question arises because the column stood behind the Basilica Ulpia (an enormous three-story public building). Was the basilica tall enough to block a view of the portrait of the emperor on the column? Wouldn't the emperor have wanted people to see him looming up as they entered his impressive public space, his expensive gift to the citizens of Rome? Once we have a 3D model, we can simulate a visitor entering Trajan's Forum, and we can prove that it was, as expected, possible to see Trajan's statue: the basilica didn't block it. (Frischer, 2008)

For the first time since the city was still intact and one could see how the buildings were standing in relationship to one another.(Orkelbog, 2010) This is a clear example of how the perspective can influence how people comprehend a place. In HTT the perspective doesn't only represent past and present, but four different hills from different times. It is possible to see, compare the hills to each other and move around the constructions to see them in detail. The alternative option, which is looking at models of the hills in the museum or pictures, would not have the same visual effect. The better the hills and surroundings are represented in the 3D world the more real the experience will feel. The testers concluded that application contributed to a better understanding of scale and that they could more easily understand the differences in size comparing the four hills included in HTT.

Another factor that would enhance the experience even more is weather and lighting adjustments. Wither et al. describes experiences with matching conditions in their paper on "Indirect Augmented Reality". In their research they replace live camera view with previously taken panoramic photos in an AR application. By doing this they improve the perceived quality of the tracking while keeping a similar overall experience. In indirect AR the virtual content was perfectly aligned but it does not represent the world accurately. If a person walks by in front of the user she would be occluded by the panoramic picture, while her legs would still be visible as it is underneath the device. The picture can only represent a certain time of day and will thereby depart from reality as the weather won't match or the shadows are cast in

[20] Rome Reborn is an international initiative whose goal is the creation of a 3D digital model of ancient Rome from the year 320 A.D. when its population was at its peak. (Rome reborn: http://www.romereborn.virginia.edu/)

a different direction. This will also be the fact in HTT. Wither et al. concludes that even if the world is not represented accurately the inaccuracy is not crucial for the overall experience. In comparison dynamic occluders can drastically alter the experience in a traditional AR solution. By dynamic concluders they refers to virtual content that does not match the live camera view, breaks the link between the physical and the virtual content and thereby looks visually unappealing. (Wither et al., 2011)

5.2.1 User perspective

After extensive testing I realized that the user's interest, knowledge and background play an important part in how the application is used. Since Holmenkollen is both a tourist attraction and a place where people interested in ski jumping and skiing in general visit, a variety of people gather there. I will divide the users into four categories. The first category is the ski jumping fans. While observing tests and visitors in the arena I discovered that the majority of the people with a great interested in ski jumping come from countries that are known for their long and successful ski jumping tradition like Germany, Japan, Finland, Austria and Poland. These visitors have a broad knowledge of ski jumping, they are interested in all aspects of ski jumping but they are also searching for information about their fellow countrymen and idols. Two polish people participated in the test. They showed a lot of interest in the whole content, but still commented that they wanted more information about profiles of famous ski jumpers. In the second category are the people who are interested in the place Holmenkollen and its history. These people have great respect for and knowledge about the old arena. They are really interested in how things looked before: Looking into every detail in the 3D models, switching between them many times and enjoying old pictures from the arena. *K. Kromann* was part of this group. He spent a lot time studying details in the 1982 hill to see if it coincided with his memories. The third group contains the average tourist, people who have no real interest in ski jumping, but see Holmenkollen as a place of beautiful scenery, a nice ski museum and on the list of things to do when visiting Norway. They go through Holmenkollen the way they visit other museums or sights with desire for an interesting experience. The last group is the people who have a strong attraction to new technology. These people focus less on the content and more on the functionality of the application. They have good skills navigating and exploring the 3D world but don't see the detailed information integrated in the application.

The variations we see in possible users make it difficult to design an application for one specific group of users. I would say that a PSC approach would be wiser than a user-centric approach as the main objective of the application would be to enhance the Holmenkollen experience.

5.3 Augmented Reality

Augmented reality is a real-time view of a physical, real world environment. Computer generated sensory input such as sound, video, graphics or GPS augment objects in this real world environment. As a result, the technology functions as an enhancement of one's current perception of reality. By contrast, virtual reality replaces the real world with a simulated one. With the help of advanced AR technology the information about the real world surrounding the user becomes interactive and digitally altered. Artificial information about the environment and its objects can be overlaid on the real world and in such a way gives it more or new meaning. (mashable.com, 2011)

Even though HTT cannot be described as traditional AR, I will, in this analysis, attempt to show why it is important to see this sitsim in the light of AR theory.

Figure 37: AR-view

The 2011 view in the application is seen through the camera of the iPad 2, with computer-generated graphics on top. The camera-view is AR in the sense you would say that sports broadcasts is AR. It has strong visual ties between the virtual content and the physical world, but no world knowledge (Milgram, 1994 pp. 11-12) as there isn't any location awareness functionality in this view. The interactive content is activated through a list menu. (Fig. 36) When this menu is opened it floats arbitrarily on top of the real-time camera view with no direct connection to the world. If the user travels to the top of the hill tower and wants to see the “helmet cam” video, which takes the user through a jump in today’s hill, they will need to access the menu and activate the right link for the video to start. The application itself has no knowledge about the user’s position or at what position this information ought to be activated. The 2011 view is not fully developed as I will discuss further in chapter 5.5.4 Further developing the 2011-view. The three other views of HTT they are similar to all the other *sitsim* applications, as they have a non-mixed ‘clean screen’ solution as Liestøl calls it. (Liestøl et al., 2011 p. 175) The *Extent of knowledge* (see chapt) in these views is strongly present, as the application has knowledge of the user (device) movements, and also of the links in the terrain and what type of content they contain and where they are positioned in the 3D world.

While some have argued that *sitsim* cannot be defined as AR but rather a mobile VR, MR at most, Liestøl and Wither et al. conclude differently. They have both developed alternative AR solutions which in some ways are quite similar. The two applications both have a synthesized version of the real world on the screen, but while *Indirect AR* has a representation of today’s terrain and objects, *sitsim* represents something from a different time. Another factor that separates the two solutions can be found in Milgram’s “*A Taxonomy of mixed reality visual displays”*, where he describes reproduction fidelity (RF) in both real and virtual objects. RF deals with the issue of realism in MR showing that as image quality is important for immersion and presence within the display.(Milgram, 1994 p. 11) Wither et al. describe the fidelity as higher in *Indirect AR* than in *sitsim* as the former uses photos and the other 3D graphics. A virtual remake will have lower fidelity than a high resolution picture, but even in such a 3D model fidelity plays a big part in the acceptance of the application. Detailed objects and life like texture is an important part of the presentation and can be decisive in determining how credible the application aappears to the user.

Extent of presence metaphor is Milgram’s third dimension, and it stresses the importance of achieving multiple scopes of view by tracking the users’ movements. The level of immersion is being measured on a scale starting with a user who peers into a world to a situation indistinguishable from directly viewing reality. (Milgram, 1994 pp. 11-12) Wither et al. describe immersion as less important for some applications that others. They believes immersion into AR applications is less important because the user’s primary focus is the completion of a task, while in entertainment or game application the focus is primarily about exploring the environment. In the sense of immersion *sitsims* have are more similar to computer games as the exploration of the 3D world is important for the experience of the application. (Wither et al., 2011 p. 815) This was also mentioned during user tests when they were asked what they liked best about the application; “Liked the videos the most – and exploring for more information (treasure hunt)”, “Exploring – walking around – Get an impression of how things were in the past – touch screens are fun”. (Orkelbog, 2011b)

More important than the immersion would be strong visual ties between the content and the physical world. However this is not possible unless registration is good enough. The real and virtual objects in the AR environment must be properly aligned or the illusion of a joint environment will be compromised. (Azuma, 1997 pp. 9-18) Any registration error can have a huge negative impact on the overall experience. (Wither et al., 2011 p. 812) (Azuma, 1999) It is difficult to say exactly how much tracking errors influence the AR experience. In outdoor AR the objects are generally far away. Even small amounts of orientation errors can result in large amounts of registration errors. *“For instance, at 20m, only 5 degrees of orientation error will generate 1.75m of registration error on a perpendicular plane Ten degrees, a not uncommon amount of error with standard sensors, will generate 3.53 m of registration error.”* (Wither et al., 2011 p. 812) In *Indirect AR*, alignment of the virtual annotations and the panorama are always perfect, even if the registration between the device and the real world are not. This can be explained by the concept visual capture. (See chapter 3.2 page 33) Like in *Indirect AR* registration error in *sitsim* is not as evident as in traditional AR. For similar reasons the user’s mind adapts to minor registration errors and the real and virtual seem to align. The technique used in *sitsim* is different as the world is created as a virtual environment. In HTT the terrain was 3D modeled from an imported digital map segment of Holmenkollen. As a result the terrain in the virtual world, and what the user sees in the real world, have exactly the same shape and creates the necessary alignment. Large registration errors won’t be accepted by the user as they make both movement and interaction difficult to accomplish.

5.4 Place oriented design

In essence *Place Specific Computin*g is no finished concept within Interaction Design, rather an attempt to include place and practice as well as the social, cultural and material aspects conditioning the enactment of place in the field. In contrast to a user-centric perspective which has been common in location-aware systems, PSC introduces a place-centric perspective for the design of digital systems. PSC includes the interaction between people and place-specific resources, mediated by digital systems and services, and connected to socio technical networks. There are several reasons why there has been a need for place oriented design during the last years: great development within network technology and connectivity, increased computing power and new functionality in handheld devices, many new commercial services especially within the genre of LBS, converging digital media and new forms of media productions, -distribution and -consumption. How well designers adapt to this new landscape depends not only on how well they are able to implement location in their software systems but also on their understanding of context as basis for creating meaning in interaction.

Messeter concludes on that PSC will range between a conformist view of designing, where PSC as an intervention is embodied with the existing culture of the place and serves to enhance its practices, and the more radical approach that aims to bring change based on an external agenda. (Messeter, 2009 p. 19)

HTT is trying to enhance the experience of exploring Holmenkollen in ways which are not possible without digital technology. To re-live authentic versions of earlier hills will offer a different perspective to the pictures and physical models found in the museum. The HTT has no external agenda of changing social interaction, but can give the visitors a different scope to for better understand the underlying meaning of the place.

5.4.1 Identity

To define a place you need to understand what elements that make it special or unique, that give it identity. For example a bar has an identity. The bars identity is more than the bricks that built it and can be described by many elements: the type of music, the drinks, people who are working there, people who visit the bar, the interaction among people and so on. You can also add the history of the bar and where it is situated. It can be hard to limit the boundaries of a place as one place can be part of a bigger place. A place can be small as a part of a room or big as the earth and places can be mixed together. *"Places maintain their identity through shared perceptions of their specific culture as part of their on-going social construction." (Messeter, 2009 p. 18)* Messeter described their use of sonic moodboards, collages of images with recorded sound from a place as a way to convey identity of place. Another way to do it, is by conducting a participant walk-through using a person who knows the area well to introduce it to the researcher. This method can provide a rich picture of how people experience a particular environment as they focus on the different dimensions of place. (Ciolfi, 2004 pp. 74-76)

To search for the identity of Holmenkollen both techniques can prove valuable, but since Holmenkollen is both a venue for winter sports and for tourism there is plenty of material available to show what this place has to offer. Videos, pictures and stories can be found in books, on the internet or in the ski museum. Even if activities in Holmenkollen are well documented it won't cover all that Holmenkollen represents. Personal stories can make a place come to life and even better if they are told at the place where they once happened. As I walked in the area with a Holmenkollen employee, he told me things I had never known before even if I had been there numerous times. This type of walkthrough was a real asset in the development of HTT and would have been even better if used more systematically. By using the human assets available in Holmenkollen; technical staff, museum staff and those affiliated with the sport of ski jumping, one could get a large amount of feedback to help develop the application. Using moodboards or similar techniques could also be useful in for example combining activities or histories, with atmospheric elements such as sounds related to specific geographical positions in the arena. Location specific sounds inside *sitsims* are successfully tried and could also be quite useful here. A bark can trigger the user's curiosity making her choose to interact with the story about the famous "dog in the outrun" ("bikkja i Bakken")[21], and a roar from the crowd give atmospheric effect when entering the stands in the 3D model. Both of these sounds are essential elements in the history and culture of Holmenkollen and give the application more life.

5.4.2 Designing a place

The history of Holmenkollen could very easily have been very different. Many times during the years, there have been disputes about reconstructions and reconstruction costs. The ground

[21] The Red Cross sold hot broth and hot dogs in the arena during a competition about 50 years ago. A stray dog was tempted by the smell, and ran across the outrun as a skier came down the hill. This event was for many years repeated by tempting a dog to run across the outrun in remembrance of the event. The dog has now a statue close to the museum.

on which the ski jumping hill is built is not really suited to the one situated there today. It is too big. The outrun has been dug out several times, to make the hill size bigger. Before the last reconstruction one considered moving the hill over to Rødkleiva, a nearby area better suited for a larger hill. This idea was rejected however because of the site's historical and social importance. This is also what PSC in fact supports:

> Arguably, place-specific computing becomes part of the continuous construction and re-construction of place, supporting established social practices but also adding to the potential to shift meanings and interactions so that places can develop in new directions. (Messeter, 2009 p. 19)

A part of these dynamics is to keep alive those phenomena or spots in a place that can be forgotten; a "non-place" as Messeter calls them. These are locations with a specific functionality that may not be needed any more or where the use has changed. In Holmenkollen an example of this is "Gratishaugen", a knoll close to the hill where spectators could watch the competitions without paying. This knoll isn't used in that way anymore, and could easily be forgotten. An application like HTT could help keep such information alive.

"The stance we take as designers towards place-specific computing is very much dependent on how we conceptualize place."(Messeter, 2009 p. 18)

I think it is useful to apply an interaction design like PSC when developing an application like HTT. Holmenkollen is a place with a rich cultural and historical background with a strong social context. The place has one million visitors per year but they come from all layers of society. It would therefore be a wise choice, in my opinion, to focus more on retaining the essence of Holmenkollen than to try to build an application for a specific group of users. HTT should focus on augmenting the hill, its activities and surroundings without changing interactions or practices in the arena.

5.5 Limitations, improvement and further Development

5.5.1 Limitations and bugs

Smartphone and tablet applications have a few common weaknesses when it comes to outdoor usability. The weather can be a challenge, ironically the weather should neither be too good nor too bad as sun creates considerable reflections on the screen and makes it hard to see what is going on, and rain or snow does not work well with unprotected technology in general because of moisture. Cool weather as I mentioned earlier results in limited response from capacitive screens as low blood circulation in the fingertips gives the finger a weakened ability to cause electrostatic changes while interacting with the glass surface.

Atmospheric conditions as space weather[22] can also affect the accuracy of any GPS receiver. When charged particles ejected from the Sun arrive at the Earth, they can cause perturbations in the geomagnetic field but also affect the electron density in the ionosphere. GPS use radio signals from orbiting satellites to determine the position of the receiver. The radio signals must pass through the ionosphere and in doing so they are subjected to variations in the electron density structure of the ionosphere. Changes in the electron density can change the speed the radio waves travel and cause a propagation delay in the GPS signal. The delay varies from minute to minute and can last for several hours. (Canada, 2011)

Some even claim cloud cover could also absorb and reflect the sat signals. The magnitude of this effect will be determined by the receiver, high end products less so than consumer handheld. Other issues could be *signal multipath* which can occur when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver, *receiver clock errors* as the receivers clock is less accurate than the atomic clocks onboard the satellite, *orbital errors* inaccuracies of the satellite's reported location, the number of satellites visible to the receiver or when Satellite geometry/shading happens and when the satellites are located in a line or in a tight grouping and give poor geometry. (Garmin, 2012)

Clear weather will in most situations give the best signal. Difficult weather conditions can be helped by accessorizing with items like an umbrella which can be helpful in both rain and sun and touchscreen gloves in cold weather.

Testing HTT revealed several bugs and problem areas that would need to be attended to for the application to be commercialized. Visually there are issues regarding the geometry in the 3D which needs to be adjusted. In two of the hills a few walls are see through because of issues with *backface culling. "Backface culling is the process by which polygons (usually triangles) that are not facing the camera are removed from the rendering pipeline"*. *(gpwiki.org, 2011)* Because of time limitation in the production phase these walls were never

[22] Space Weather: "Conditions on the Sun and in the solar wind, magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health." SOHOWWW.NASCOM.NASA.GOV. 2011. Space Weather [Online]. http://sohowww.nascom.nasa.gov/. Available: http://sohowww.nascom.nasa.gov/spaceweather/ [Accessed].

fixed for testing on the prototype. The models could also be visually improved with more extensive use of textures in order to create more detail.

During the testing of HTT I found a problem regarding navigation. Since navigation in a *sitsim* is controlled by the user's movement and the user's movement is guided by the GPS the accuracy can sometimes be poor. It can even jump from one position to another if the device has poor connection to the GPS satellite. This unexpected movement can occasionally cause the user to be positioned in between objects. If this Geometry had been solid there would have been a great chance for the user to get stuck in the geometry with no possible way out. But in the HTT the only solid part of the 3D geometry is the terrain, the ground the user walks on. This choice resulted in the user falling through the stands on the sides of the landing area on both the 1952 and the 1982 hills. To work around this error during the test I was forced to use the "birds view" feature to float in the air above the stands in order to move over them instead of underneath them. Using the "lever" on the side made it possible to adjust the height so it seemed as if the user was walking on the stands. Since it is not possible to interact with the links in the bird view I had to place the links on alternative positions in the terrain, resulting in poor coherence between links and content. E.g. the judge booths in the 1952 hill were situated in the stands. To describe style and distance points in ski jumping I made a links to web content which was placed close to these booths in the stands just beneath the windows where the judges used to sit. This became impossible because of the above mentioned limitations with movement. I ended up placing the links close to the stands, which didn't really correspond well with the content. This again made the user wonder why the link was placed next to a tree when it was describing the ski jumping judges and point giving. Further development should solve this problem and make certain parts of the geometry solid for movement purposes.

There is also a bug going from video projection inside the application back to the 3D models. When opening a video the YouTube application takes over. If the user opens this video in full screen and goes back to the terrain in the simulation the window is rotated 90 degrees clock wise and HTT needs to be restarted for the screen to rotate back.

There is also a problem with the user links. The user links work, but can't be placed too close to each other. A user during the tests put a link almost on top of another one which made it impossible to get to the menu in the 1952 hill as one overshadowed the other.

5.5.2 Copyright

HTT has a collection of pictures and videos stored on a webserver. The multimedia content is a compilation of my own material from Holmenkollen and material found online. As this is a proof of concept application which has no intention of being commercialized and with a closed user test, I have not been concerned about seeking permission from the right holders to this material. Since the data is stored on the web, I had to do some modifications to the HTML to make the content not searchable. The same was done with the videos. The pages with text are stored as picture files (.GIF and .JPG) to prevent them from being searchable. The picture files have names that cannot be linked with the content of the picture itself. There are also no Meta data stored in the HTML. As for the videos, they are stored in YouTube. Preferences in YouTube allow the user to control privacy settings on each video uploaded before sharing. The videos are set as *unlisted*, which means that only those who have the link can view it, and they have no description or tags affiliated with the name. As a result of these modifications you would have to have the link to the pages to be able to find them online. Through these precautious modifications I believe I'm not breaking the exclusive rights to the material used in the application.

5.5.3 Further development

Several ideas were never implemented in the prototype. Some of these ideas were part of the original vision, other ideas were thought of in the testing phase. Completing some of these ideas would definitely make the application more extensive in detail and also give it a richer visual experience and functionality. First of all I would extend the application to include all big developments of the ski jumping hills in Holmenkollen. In the prototype I have focused on four hills, but the simulation could easily be extended to contain at least three more hills. The first tower was erected in 1914 with the height of 9.5 meters and it caused a lot of controversy. Towers in ski jumping hills were at that time described as an abomination. The Americans who were already building inrun scaffolds in steel were mocked in the newspapers in Norway. When this tower collapsed in 1927 because of heavy snowfall a new one was built and finished in 1928, the first hill with ski jumps with the length of over 50 meters. After the Olympics in 1952 Norway again applied for the Nordic ski world championships and to satisfy the demands of FIS (International Ski Federation) the hill again had to be extended and improved. The hill was completed in 1963 ready in good time before the events in 1966. Both during the production and the testing phase I was quite unsure of whether it would be better to build today's hill in 3D. Because of time issues and of the extensive detail of the new hill, I decided to present it through traditional AR. At that time I knew little of the difficulties regarding the implementation of links. AR has the reputation of being inaccurate in its presentation of content; *sitsim* on the other hand does not have the same problems. The reason for this is that traditional AR has fewer options when it comes to disguising the GPS inaccuracies. Say for instance that an overlay will highlight a certain building in a street. GPS coverage is poor and the overlay on the building is not aligned properly or even worse partly covering the two buildings. This kind of alignment error can be very distracting and in some cases damaging for the experience. When using a situated simulation, the user's real perspective is almost identical to the visual perspective in the 3D representation on the screen. But since the user isn't seeing the exact same thing on screen and in real life, the user has to mentally combine the two visual impressions to understand them as a combined reality. In this combined reality perfect accuracy is not required for the user to accept the application. Marginal positioning errors are overlooked and the coherence between the two remains strong. Since I had chosen to use AR in the 2011 view, and placement of the links was close to impossible to implement in a satisfactory way, I ended up with a dock menu like earlier described. The 2011 AR view was always a sort of backup solution. For further development a number of solutions could be considered. The first option would be to keep the AR solution but improve it. During user tests some comments were made on this subject. One reaction was very positive towards AR;

"3D gives a better perspective sometimes as the camera-view "gets too close" on the objects. But still I didn't want to change the camera view to 3D because then it feels like making history out of something that is present time. In other words I liked the distinction that camera is reality and 3D is history." (Orkelbog, 2011b)

For those positive to the AR solution most of them wanted more content like the links found in the 3D view.

"Links in the 2011 view so the user could interact with the content here as well" (Orkelbog, 2011b)

"2011 view should get more stuff – add buttons somehow – add NFC support maybe, to get the 2011-mode more interactivity, "balloons" (links) in the same way as the other years" (Orkelbog, 2011b)

5.5.4 Further developing the 2011-view

Near Field communication (NFC) is a form of contactless communication. NFC communicates from device to another device or a certain type unpowered NFC chip, called a "tag". Radio communication I established by touching them together or bringing them into close proximity. The standard is supported by the NFC Forum which consists of leading cooperations such as Philips, Nokia, Sony, Visa, Microsoft and Panasonic. Contactless infrastructures are already in use in public transportation and ski elevator systems. There are three different modes for NFC. The first mode is when an initiator, the active part, communicates with a passive device or a tag. The second mode is when a device emulates a tag. It is when an active device is used in a passive way. The third mode is two active devices communicating. There are different tags on the market and the speed and the size of the tags are different from type to type, but in general they vary from 48 bytes up to 1 megabyte in size. The use of NFC is making it simpler to make transactions, exchange digital content, and connect electronic devices with a touch. (Berget, 2008, nfc-forum.org, 2012) In the case of HTT, NFC could be used to improve the AR functionality. By using tags the user of the application can access URLs so that a webpage can be opened on the device. For instance if a user of the HTT walks over to the statue of Fritjof Nansen outside the ski museum, a tag is placed on the statue itself and the device communicates with the tag when it gets close enough. On the tag a URL is saved, which can be read by the active device and opened. In such a solution the AR solution will not be dependent on accurate GPS signals to be accepted. One problem though is the availability of devices with NFC functionality. None of Apples products have yet acquired NFC features, but it is speculated that it will be introduced in their devices in 2012 as Samsung, Google, Nokia, Blackberry amongst others are NFC-enabled.

A different solution would be to model the 2011 hill in 3D and give it similar functionality as the other hills. One of the testers commented:

"I want it in 3D. The perspective gets distorted when you go from 3D to camera view. Maybe I would add a menu like the one in 3D view." (Orkelbog, 2011b)

In the interview Kromann concluded after being asked the question whether he would like to change something in the 2011 view:

"I would like it to be a 3D model as well, first of all because the 3D simulations give a feeling of stepping into something, when the AR version is more like holding a camera. In addition to the perspective it seems to me that it is easier to adapt the 3D view to content production and I would like the 2011 view to have links as well. Maybe it is even possible to have a fly-in rendering into buildings. Like the museum." (Orkelbog, 2011a)

Fly-in is a functionality used in later versions of *sitsims*, where the user-position is moved by a 3D real-time rendering inside the VE. Some real geographical positions are not reachable when using a *sitsim*. Object from the past being represented in a *sitsim* can today be inaccessible because of certain obstacles in the geography. i.g. buildings or fences. An example of this can be seen in a new version of the *sitsim* Temple of Divus Iulius. The area, in which the temple is situated, is now inaccessible for visitors. To get to the inside of the temple the fly-in feature is utilized:

"When in the proximity of, and activating the link named 'Fly into the cella', the virtual camera embarks on a movement into the middle of the Cella chamber. Users may not manipulate the orientation of the camera while it moves. When in the locked position inside the building, the camera can be moved and oriented by means of panning and tilting. In this way one can observe the interior in more detail. In this feature we see a full displacement of the position, but only a part detachment of orientation." (Liestøl et al., 2011:183)

Such a *fly-in* would be interesting in HTT to show the judges' booths and their view of the hill, the museum, taking the user to the top of the jump tower or to give a fly-by overview of each of the hills with voiceover commentary.

Kromann also expressed a wish for a more detailed representation of the surroundings. He specified that he would like more of the buildings in the Holmenkollen area included in the 3D models. He mentioned especially Kollenstua, the museum building completed in 1983 and the statue of Fritjof Nansen. To expand the 3D world is a real challenge. As discussed earlier the graphics engine of the iPad 2 has limitations. Adding objects to the "world" may result in less detail in the hill construction.

Sounds can be an important part of an experience. Bill Gaver explains the qualities of sound in the book "Designing interactions"(Moggridge, 2007). Sound conveys very different information than vision does. Vision is light that bounce off surfaces, part of it gets absorbed and the rest gets modified and passed on. The light that reaches our eyes contains information of color, texture and so forth and we get knowledge about surfaces laid out in space. Sound works differently. A sound is created when an object starts to vibrate and the way it vibrates depends not only on the surface of the object, but also on its internal configuration as well as the interaction that causes it to make the sound. The sound, like the light, bounces off the environment before it reaches the ear, but it conveys more information about the source than about the environment. The sound qualities of an object can be in harmony with the visual impression of the object but it will tell you different things. I can e.g. communicate emotional qualities rich with connotations.(Moggridge, 2007:577) Many sounds experienced in Holmenkollen are carriers of emotions and describes objects and actions. Sounds like skis running down the inrun, the sound of a jumper in the air, the man on the speaker introducing the jumpers and the world famous Holmenkollen roar when the spectators scream as the skier comes flying through the air. The acoustics in the arena give away sound of a special character and gives the spectators a more complex experience. One tester commented *"I want more visual content like spectators, sounds and other stuff that makes it more exciting to navigate and explore the different times."(Orkelbog, 2011b)* There are a lot of possibilities when developing an application for a famous place like Holmenkollen especially when it comes to applying social aspects like atmosphere and social behavior. These are the human factors that make a place special. Implementation of sound is an important element, and in my opinion an essential goal for further development of the application.

Another idea that was part of the original vision for the application was a simulation of a ski jumper in each of the 3D modeled hills. This ski jumper would have the right clothes, equipment and the right technique for the hill and the year. The jumper will make the hill record for the specific hill and give insight into the development of ski jumping. This proved way too difficult to manage within the frames of this thesis, but it would have been informative and cool.

6 Conclusion

In this thesis I have described and analyzed the development and testing of the iPad application Holmenkollen Time Travel. The application is my attempt at making a location-aware application that introduces new functionalities to the concept of Situated Simulation. The application was tested by four different user groups, and it is their feedback, (in addition to my own experience and analysis), that creates the basis for answering the research question on how the application, both in the form of the existing prototype, potentially through an eventual commercialized application or similar applications, can contribute in enhancing users' experience of a specific place. I have used theoretical perspectives of Augmented Reality and Place Specific Computing when analyzing the development of the application and its' use in order to give context to the application and the design approach.

6.1 Special features in the HTT

As said in the introduction "time travel" is not a completely new feature to sitsims, but with HTT a sitsim with the time travelling component being the main focus is developed for the first time. The four different views within the application are equally important entities, and encourage the user to explore the different stages in the history of the place and the sport.

Even if, as described earlier, "time travelling" features are to some extent used in earlier sitsims like *the Temple of JC* and *Parthenon,* I will on the basis of the emphasis on and development of these features within the HTT, argue that the HTT to some extent changes, further develop and give new knowledge about this feature.

Another significant development to the concept of sitsims that HTT introduces is how the terrain is designed. The HTT demands more of the 3D terrain because of the hilly terrain the ski jumping hill is built on, thus the terrain in HTT is created by importing official map data. This is not a commonly used method in other sitsims that are mainly geographically positioned within relatively flat terrain.

The content in earlier sitsims is usually implemented within the application itself. In HTT however the content is placed on an external web server, and accessed via links and the browser inside the application. This makes for a flexible solution and was a deliberate choice as it allowed me to edit the content without altering the application. On the potential down side this solution requires a fast and stable internet connection on location. The video content is important in HTT to document jump style and technique in the former hills. Video content, presented using the default iPad 2 player floating on top of the sitsim application can also be described as a new feature in a sitsim.

6.2 Augmented Reality and Place Specific Computing

While AR applications are mixed reality, *sitsims* are "clean" screen reality applications as they don't mix real and virtual elements on the screen. Some people argue that because of this *sitsim* can't be viewed as AR. Liestøl argues otherwise and this is confirmed by Wither et al. in their article *"Indirect Augmented Reality"*. I have in this thesis claimed that seeing HTT through an AR perspective is useful to understand the basic concepts of functionality and navigation, but also to better understand how users accept the application.

Reproduction fidelity can play an important role in AR applications for immersion and presence in the AR world. In traditional AR applications this might be more important as they are based on live footage through a camera, but also in *sitsim* it is important to create a life-like world. Wither et al. describe presence as less important in traditional AR solutions as users are more focused on task solving. HTT has a closer resemblance to computer games where immersion is important for a good user experience as they urge the user to explore the 3D world.

I will emphasize the importance of good registration in the application. Any registration error can have a huge negative impact on the overall experience. (Wither et al., 2011, Azuma, 1999) The feedback from the test users of HTT also reflects this. This is the case in both traditional AR solutions and *sitsims*, even if registration is experienced slightly different. There is a better tolerance for registration errors in *sitsim* application than in traditional AR, but if the error is too evident the application won't be accepted by the user. (See p. 65-68)

As shown in the analysis chapter, there are several reasons why choosing a direction within interaction design like Place Specific Computing (see page 37) is reasonable when developing an application like the HTT. First of all there is no typical visitor at Holmenkollen. Some have a genuine interest in the place, some are just tourists passing through and others might be very interested in the sport of ski jumping. With HTT I aim to contribute to enhancing the experience of Holmenkollen, something that is, in my opinion, impossible unless one understands the historical and cultural context and the activities of the place.

The application show how Holmenkollen has developed over time and gives an understanding of the changing social practices, thus HTT can potentially also function as a conserver of place specific knowledge that could otherwise get lost, what Messeter names “non-place” (see page 70).

6.3 The user testing – feedback

The overall feedback from the test users was extensive, and of course the individuals involved see and experience the HTT somewhat differently. However, there are some obvious issues that most of the users focus on and highlight in their feedback. These are what I base my evaluation of HTTs potential contribution to an enhanced user experience on.

Navigation and GPS: Most users found the navigation in HTT easy and intuitive, but the navigation is heavily dependent on the GPS accuracy. Especially in one area of the arena the GPS signal was unstable, most users commented on this describing that it made movement inside the application jagged, that they were wrongly positioned in the VE, and that it was difficult at times to interact with content as the “virtual camera” moved back and forth rapidly making it hard to tap the link. The GPS issues are, as mentioned in chapter 5.1.1, difficult to improve, but one way to improve the experience is to place less interactive content in the problem areas.

Content and content positions: Some content may be difficult to place (position) as it doesn’t necessarily have a “natural” position. This can create confusion for the users as they might not follow the placement logic of this content. Also when the area the application covers is wide, the amount of content is massive, and there exists parallel universes, the users can easily “get lost” in the sense that they lack overview and knowledge of information they might have missed. I had addressed this problem in the prototype by designing and placing an information sign board within the application, containing all of the content, but the users commented that this was insufficient in creating an adequate overview. Some users suggested creating an overview map with link information that would also make it possible to plan the tour (movement) in advance. This was highlighted by some users to be very useful, especially because the terrain can be physically straining to move around in. I find this feedback to be valid and relevant.

Perspective: Most users made positive comments about the application's contribution to their understanding and experience of scale and perspective. They believed that they got a better understanding of size and architectural structures of the former ski jumping hills through the HTT, than what they would have gotten by just looking at models, videos and photos. The HTT also makes it easier to imagine how it for example was to be a spectator during the Olympics in 1952, thus potentially produce more complete knowledge of place and context, as Frischer discovered in the Rome Reborn project (see page 64). Over all the users seemed to especially appreciate the time travelling experience, as one user commented; "*The best thing about HTT was to be present in the past.*"

The test users feedback show how the HTT, both the current prototype, and an eventual improved version, can enhance the users' experience of Holmenkollen. Based on this, and the general trends in the use of handheld devices, my research could be of relevance also when developing other similar applications.

Resources

Holmenkollen time travel web content is found at
http://www.minus.im/

Data from user test at
http://minus.im/resource.html

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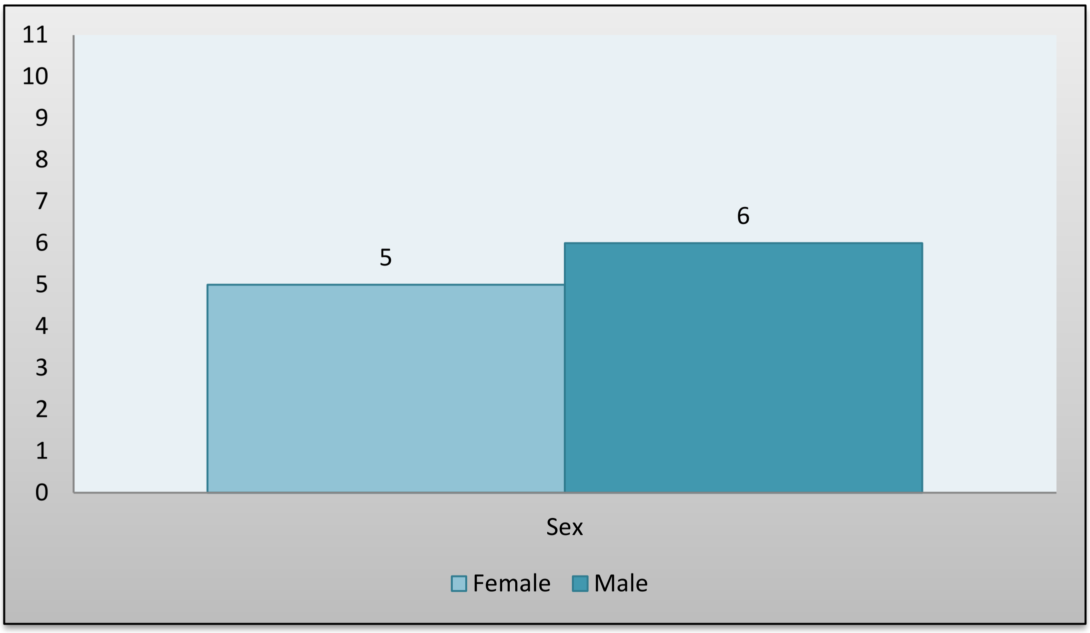
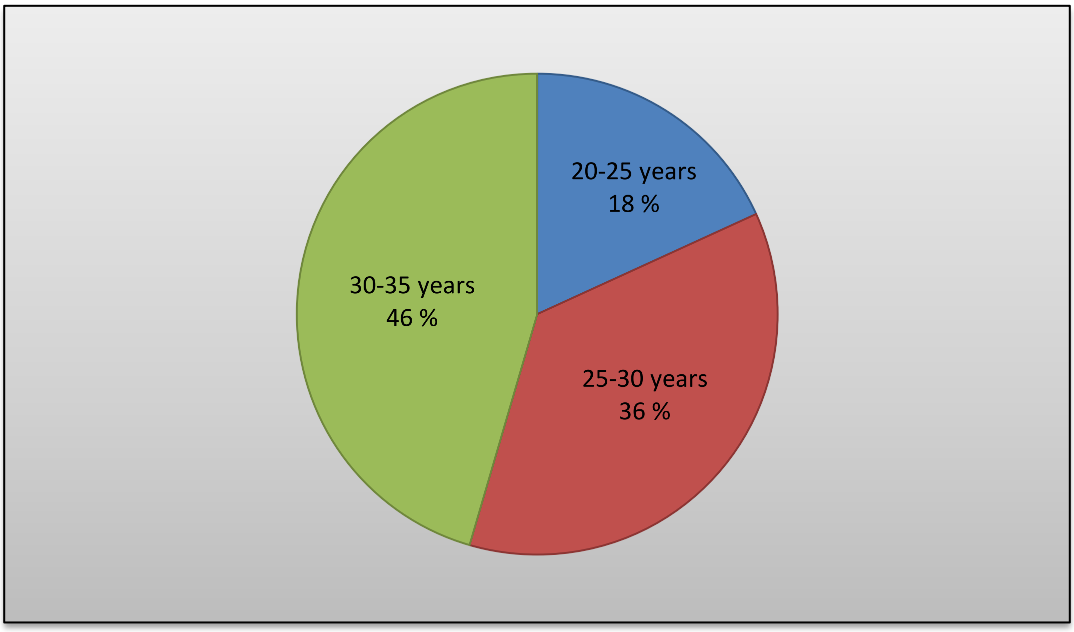
Figures

Appendix 1: Questionnaire

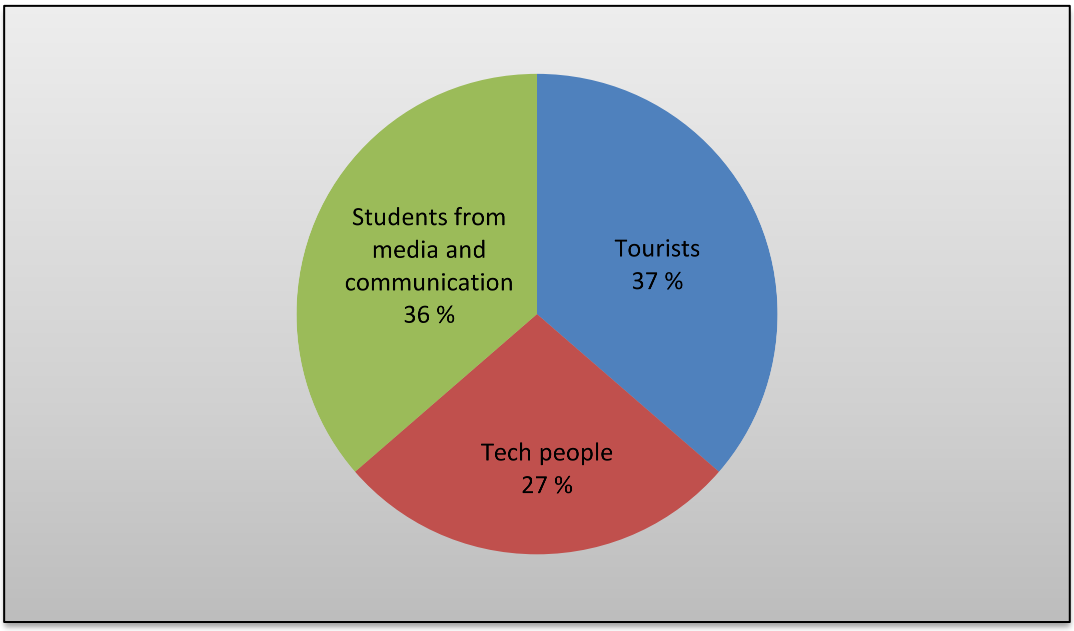
1. Sex



2. Test Users - Age

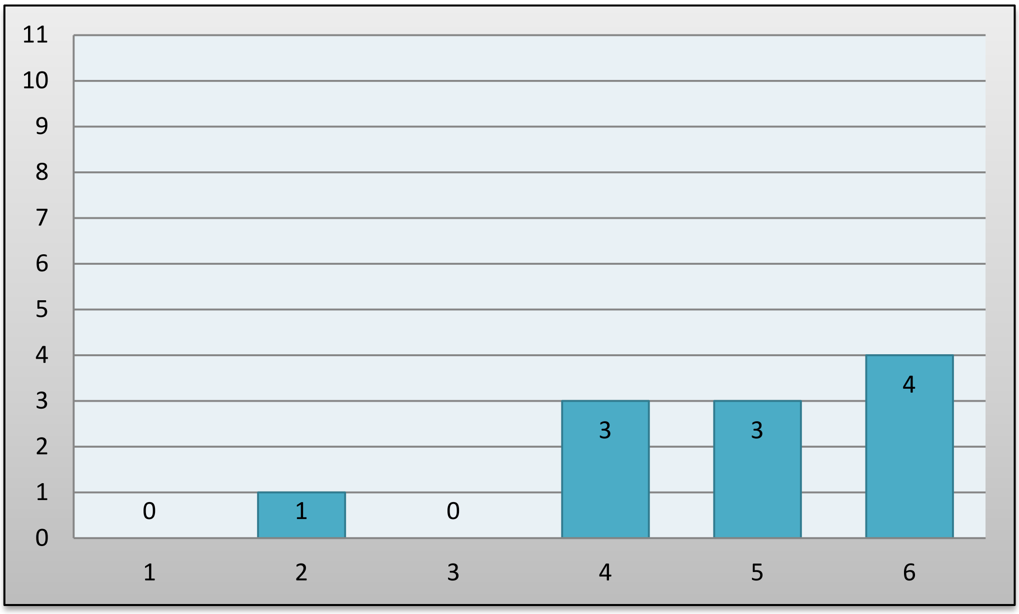


3. Selection for user testing – total: 11 test users



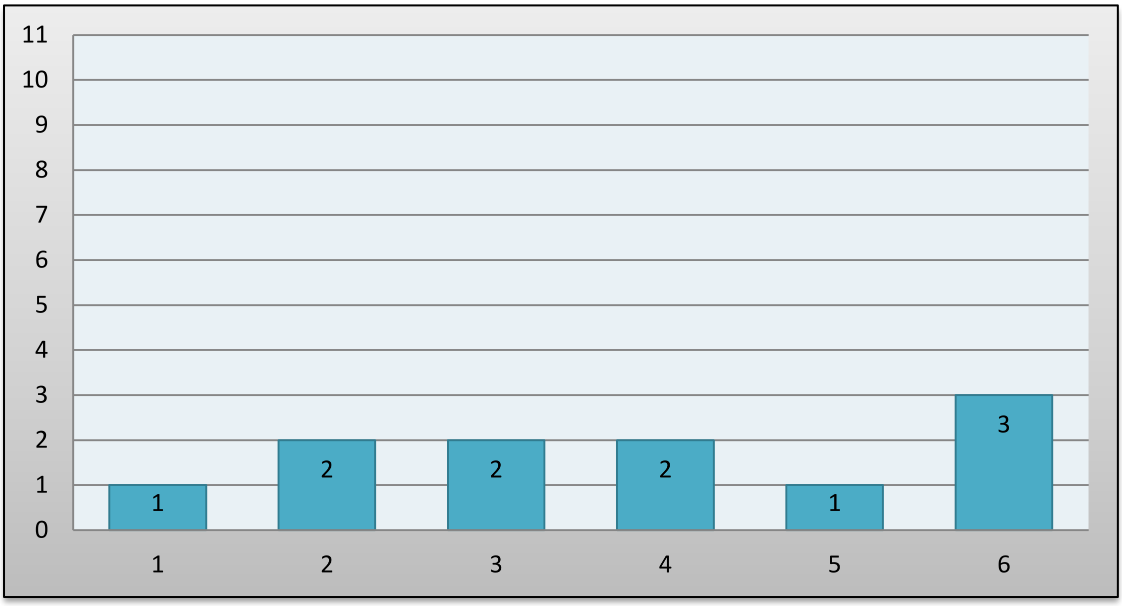
4. Do you have experience with touch screen on mobile devices or pads?

(1 no experience – 6 much experience)



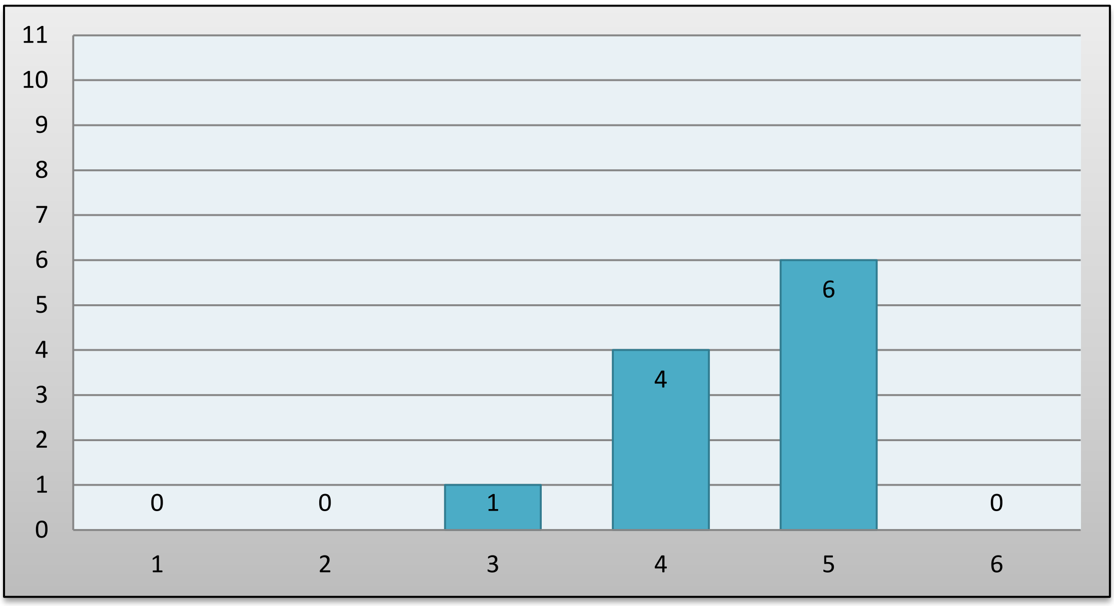
5. Are you interested in ski jumping?

(1 not interested – 6 very interested)



6. How was the experience of using the Holmenkollen Time Travel application?

(1 Very bad – 6 perfect) (Question 6 in tourist questionnaire)



7. What did you like best with Holmenkollen Time Travel?

a. Good concept and implementation
b. Links and 3D models from the different years - The information was comprehensive without being boring – exciting for ski enthusiasts – Visually good, fun to walk around
c. The possibility to see the Holmenkollen in different times
d. Travel back in time and see today vs. then – liked the historical pictures and videos
e. Liked the videos the most – and exploring for more information (treasure hunt)
f. Exploring – walking around – Get an impression of how things were in the past – touch screens are fun
g. To be present in the past

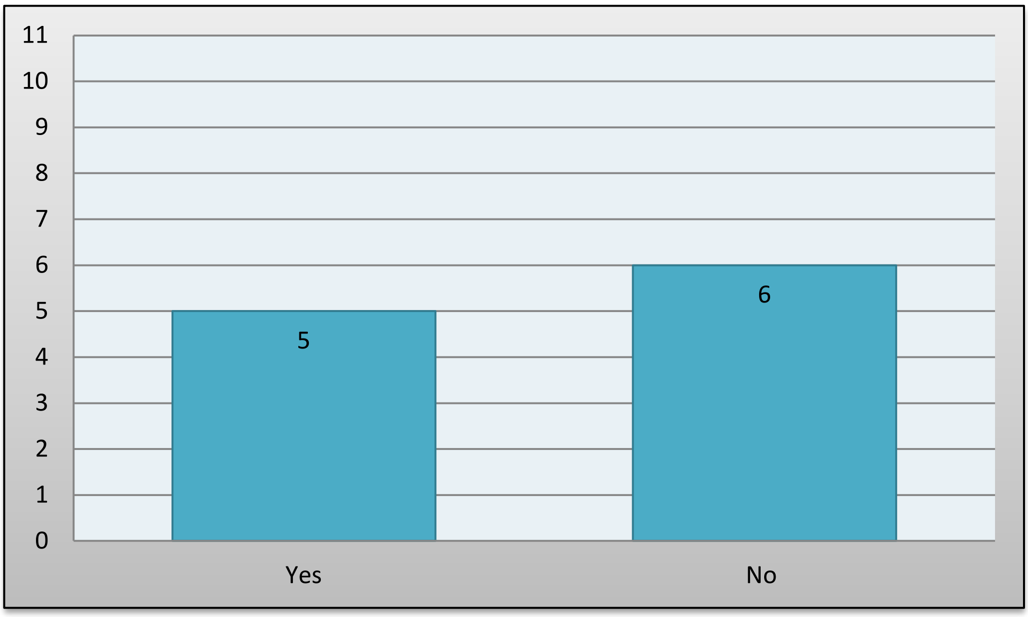
8. What did you like the least about Holmenkollen Time Travel?

a. Tiring to hold the iPad – annoying that you can't open link from a distance.
b. That you couldn't walk on the stands **– Info** web page was messy and not well arranged – GPS signal unstable (poor coverage) – WIFI same thing
c. Small things – falling through stands – positioning unstable (GPS) – Visually grey, could have more colors
d. Cold on fingers and toes
e. Would like info like in the 2011-menu (list) in the other views
f. Poor control at times – being left in the hands of a GPS
g. That I had to walk to the balloons to get the information.

9. Did you have any technical difficulties?

a. Fell through stairs – GPS signal failure – 2011 AR rotated 90 degrees when watching video in full screen
b. A few, GPS was little on and off in positioning – some links didn't work after i "added link" – some of the videos wouldn't load
c. GPS accuracy – WIFI-connection- problems with level/height in the different views
d. Some problems clicking the "balloons" and the iPad turned off at one point
e. Some problems pressing the "balloons" they didn't respond. The screen turned black sometimes, but realized after a while that this wasn't a error.
f. Only in GPS "shadow", and WIFI (data transfer)
g. Some problems with "balloons" no response while hitting them

10. Have you been to the Holmenkollen ski museum?

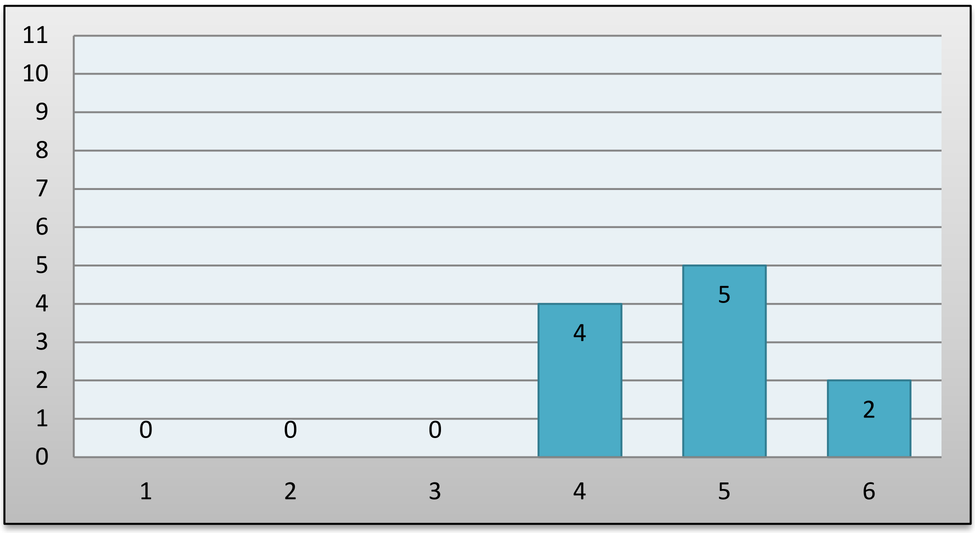


11. If yes, what did you enjoy the most at the ski museum?

a. Don't remember much, but I enjoyed the tower.
b. The royal section and the tower
c. The tower

12. Did you learn anything new about Holmenkollen through the application?

(1 no – 6 A lot)



13. How would you describe this way of experiencing the Holmenkollen history compared to being in the museum?

- **a.** More direct – probably works best as a supplement to a museum – would have been unorganized with as much info as you get in a museum
- **b.** More fun and you get to see the sight objects at the same time. It's like a museum in your pocket, you choose when you look at the surroundings and when to look at the info
- **c.** Very nice addition to a museum experience
- **d.** More participating with the app – to very different experiences
- **e.** More interactive experience – more participating in the experience as the user walks around controlling the experience themselves.
- **f.** More interesting – richer experience because I can choose what I want to see and listen to.

14. What in your opinion would be the biggest positive aspect of using HTT instead of going to a museum?

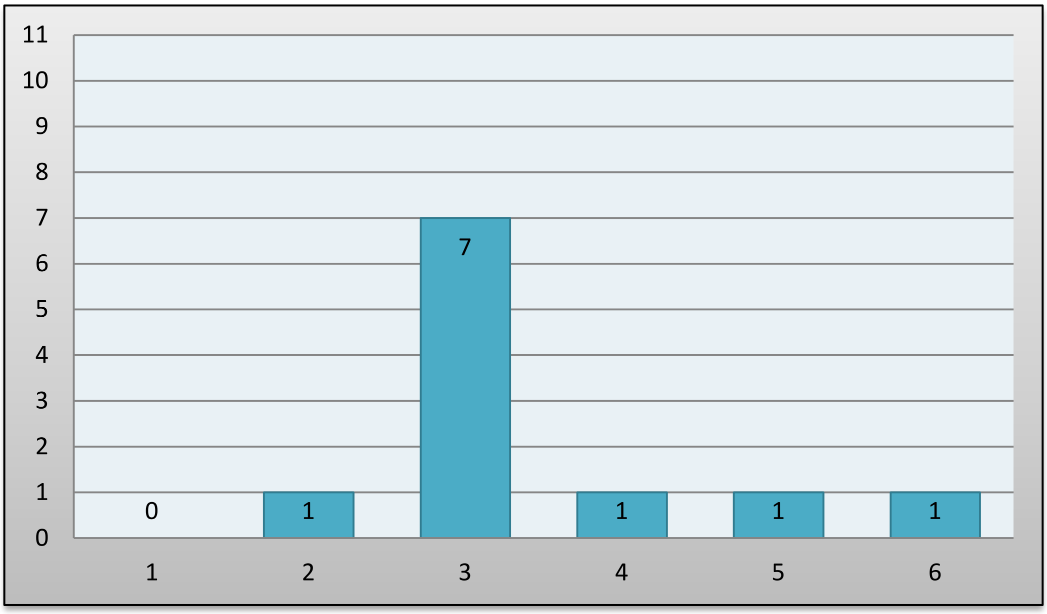
- a. Ability for people to explore in their own pace
- b. No need of indoor facilities and hired personal – People can use their phones and pads to experience something new
- c. To be in the middle of the attraction – choosing the pace for them self – to be able to stop and walk past other things – more freedom – better usability
- **d.** "live" experience – stronger feeling of presence
- **e.** More interactive experience **-** better sense of control
- **f.** More physical experience
- g. Much higher level of interaction with the content – Different type of learning where one will press and play instead of reading from a wall chart.

15. What in your opinion would be the biggest negative aspect of using HTT instead of going to a museum?

- a. Technical issues
- b. Hard to offer the same high level of information and a lot of info in HTT would very quickly get messy – HTT is also only visual, so you won't get the hands-on experience you get in a museum
- c. To much focus on screen, forgets
- d. A lot of what is in the museum is not found in HTT?
- e. For a person not used to touch screens and technology in this way, it can be a better experience to walk around indoors on level floors with carpets reading on wall charts
- f. Museum would be more authentic. To look at equipment i.e.

16. "This application is an alternative to going to the museum."

(1 completely disagree – 6 completely agree)

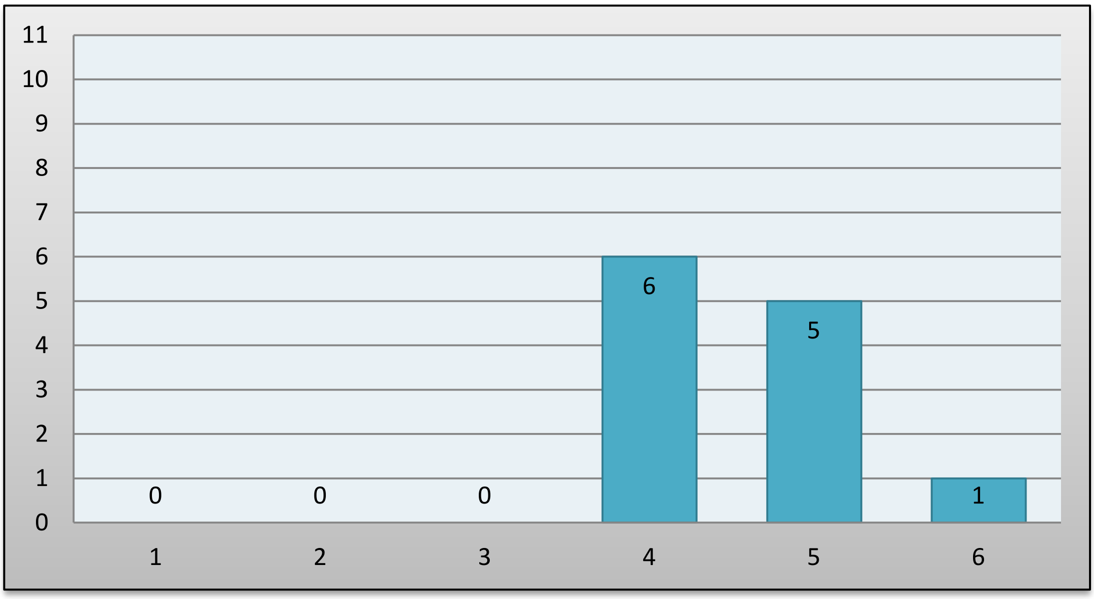


17. What would you add or change in Holmenkollen Time Travel?

- **a.** I'll give it more color, change the info menu (not clustered like it is now) – links should be easier to access – 2011 view should get more stuff – add buttons somehow – add NFC support maybe, to get the 2011-mode more interactivity
- **b.** Birds-eye map where all links are plotted, so if you can go through the links from a stationary point – Ability for people to use photo/video/sound to make new tags
- **c.** More color, more elements in 3D –use AR in 2011 – balloons links more colorful, unique – sound from the different years – overview picture with all the links (top-down view like Google earth) a possibilities to choose year which changes the links to pics from the specific year.
- **d.** A start page that give an explanation on how to navigate and use the app (like you will find in games) something you can choose not to see if you don't need to. - "balloons" could be easier to see; different color, size or shape. – I love old pictures so more of those.
- **e.** Profiles of famous ski jumpers
- **f.** Would change placement of "balloons" in the models. The 2011 model was better as the info was to a larger degree gathered in a menu

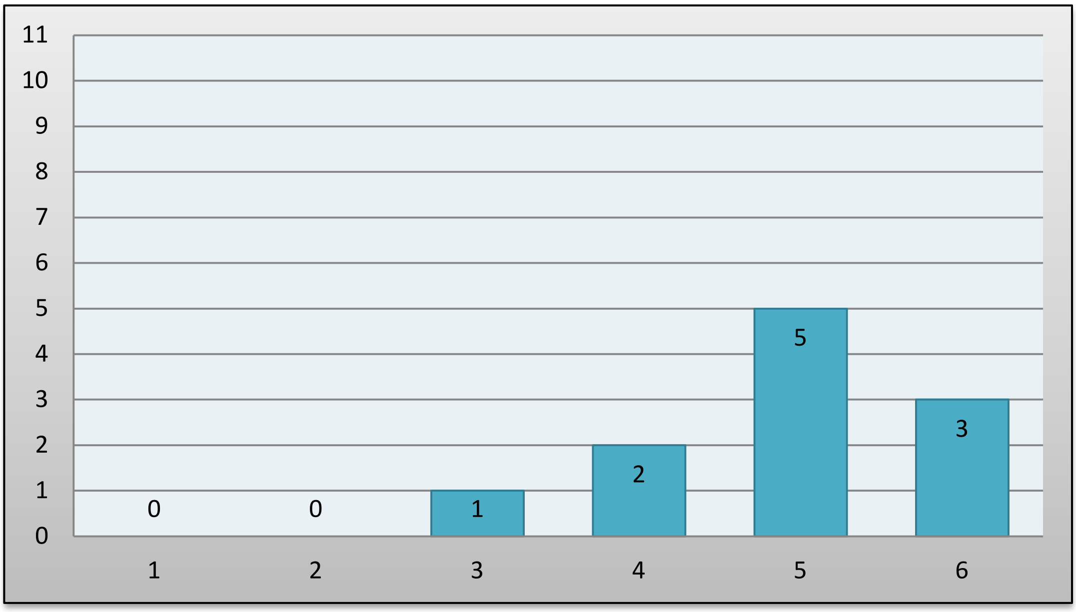
18. To what degree would you say that it was coherence between what you saw on screen and what you saw in reality?

(1 no coherence – 6 perfect coherence)



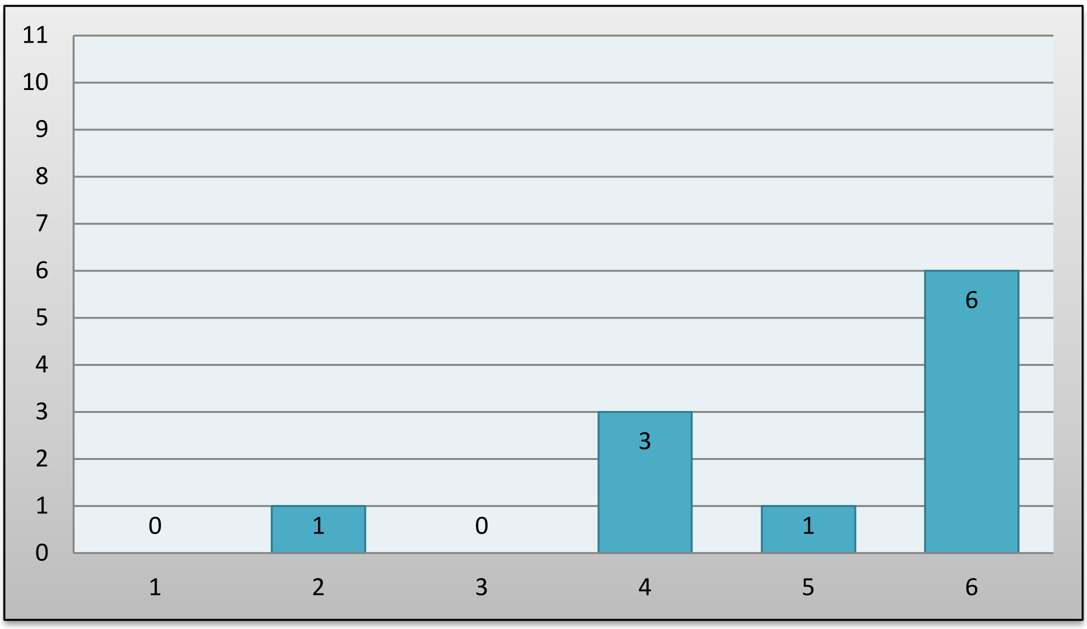
19. Did the application contribute to give you a better understanding of scale of the different hills?

(1 not at all – 6 to great extent)



20. How is it to navigate in the application Holmenkollen Time Travel?

(1 extremely difficult – 6 very easy)



21. Did you switch between the models several times or did you stay in one model at a time? Elaborate…

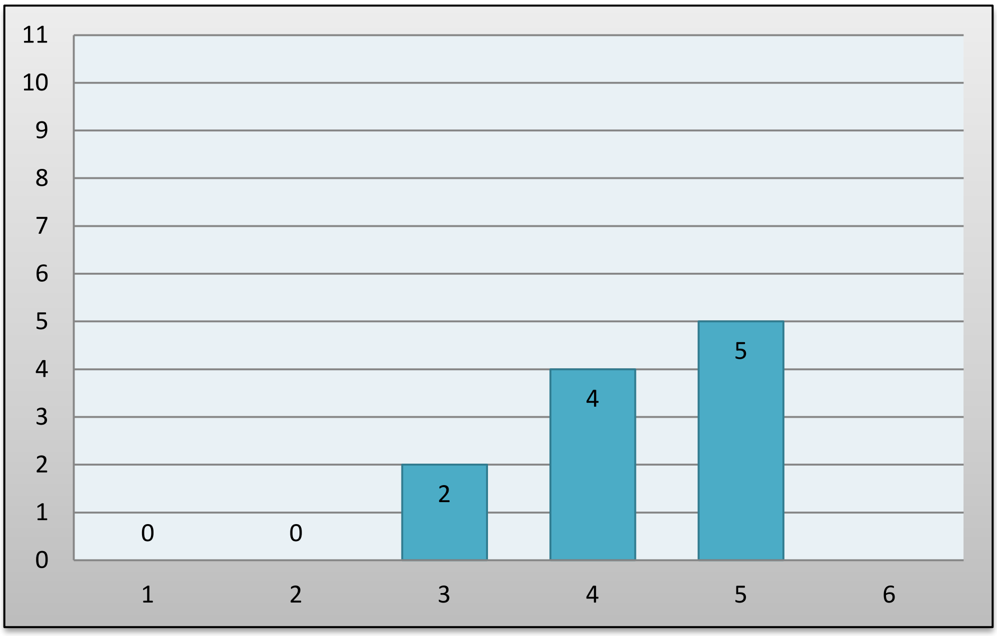
- **a.** Switched several times to see differences
- **b.** Switched many times to see the terrain and info from the different years and history
- **c.** Switched a lot between the different years, more when I came closer to the hill to see size differences between the hills
- **d.** Walked from location to location and switched between the different models. So yes I switched a lot
- **e.** Yes I switched a lot because that was one of the things I liked the best. It's fun to see the how the hill has changed through the years from different angles
- **f.** I changed often to get different info
- g. I changed a lot because I didn't want to miss any of the I "balloons"

22. The application has time-relevant content. Did you recognize this? If you did; did it change the way you navigated?

- **a.** No
- **b.** A little, the hills changed and that was exciting. Checked out the different years and the info about those years. It changed the way I navigated as I compared and backtracked in the terrain.
- **c.** Yes, but it didn't change the way I used the app
- **d.** Yes and that things changed appearance
- **e.** Navigated accordingly to how I moved
- **f.** Yes in some locations in the app. Made me go back to the hill picture and try to recognize pictures/videos in that hill
- **g.** Made med change between the hills often

23. Did the positioning of content make sense?

(1 not at all – 6 to great extent)

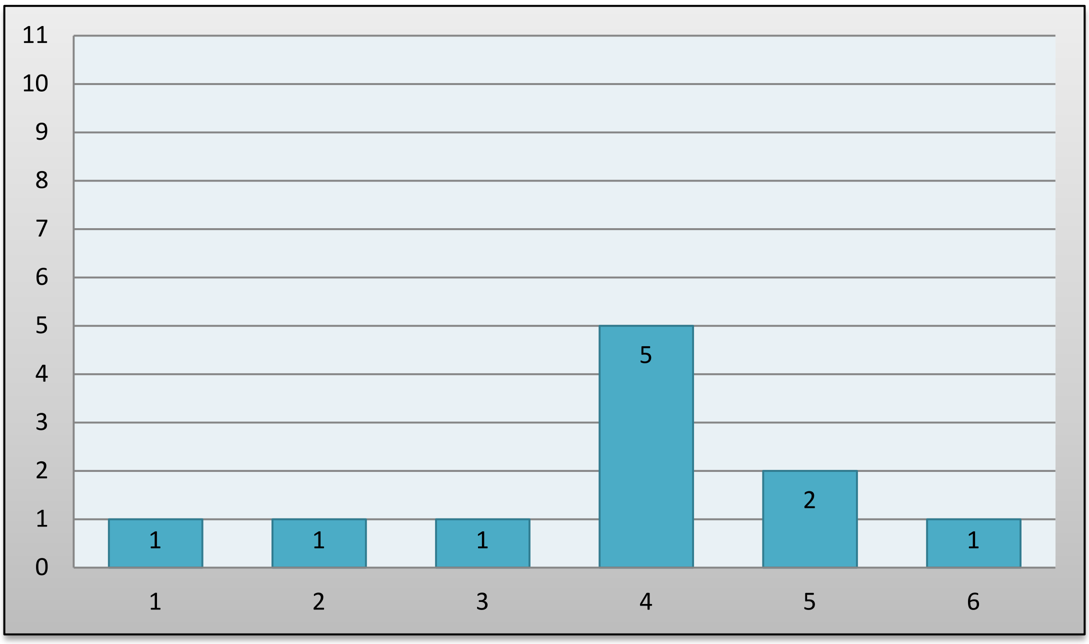


24. How could it be different?

a. Birds-eye map where all links are plotted, so if you can go through the links from a stationary point
b. Big links, better arranged or with an overview map where you can find all the links – could be a menu accessible from everywhere.
c. Could have been presented in a shared list. – It could have been the same in all years so you didn't have to change view to be sure that you didn't miss anything.
d. Sometimes I wanted 1892, 1952 and 1982 had the content collected in a list like 2011
e. I felt that some of the "balloons" were place a little random. For me it was ok because I was already there at the time, but I think I probably wouldn't see all of them if I was sightseeing by myself. Maybe it would be smart with a mini-map that showed all the information could have been included in a sort of intro start page in the app
f. The GPS changed the view in a strange way sometimes; maybe do something to keep it steadier. The view jumped back and forth

25. What did you think about the "2011 view" compared to the 1892, 1952 and 1982 views?

(1 significantly worse – 6 significantly better)



26. If you could change the "2011 view", how would you like it to be?

a. Insert tags like in the other views. It didn't add any info that you cannot see in reality
b. Links in the 2011 view so the user could interact with the content here as well
c. Like said before, NFC, "balloons" in the same way as the other years
d. I liked photo-view, didn't want it as the other views. 3D gives a better perspective sometimes as the camera-view "gets too close" on the objects. But still I didn't want to change the camera view to 3D because then it feels like making history out of something that is present time. In other words I liked the distinction that camera is reality and 3D is history. It would be nice though if the camera-view was zoomed out a bit.
e. Wanted the same type of balloons in this view, but most of all I would like to have the 2011 menu in all of the views
f. I want It in 3D. The perspective gets distorted when you go from 3D to camera view. Maybe I would add a menu like the one in 3D view.

Additional Feedback

a. I would like to have the links more available but I would like them to be in the terrain – more visual content like spectators, sounds and other stuff that makes it more exciting to navigate and explore the different times.
b. It was fun and exciting, but I would like an introduction to functionality and how to navigate and where to find info
c. Liked the app, more interesting than the museum
d. Exciting and informative, it is a supplement for the museum
e. Consider weather, maybe not always it is possible to use the devices
f. Very good idea! Great way to learn something new
g. More user friendly balloons. Be guided to them.

Appendix 2: Link placements

1892-bakken

1: Name – “1892” - http://minus.im/1892.html

2: Name – “Ski Jumping” -http://en.wikipedia.org/wiki/Ski_jumping

3: Name – “Hill Description” - http://minus.im/hill.html

4: Name – “INFO” - http://minus.im/word.html

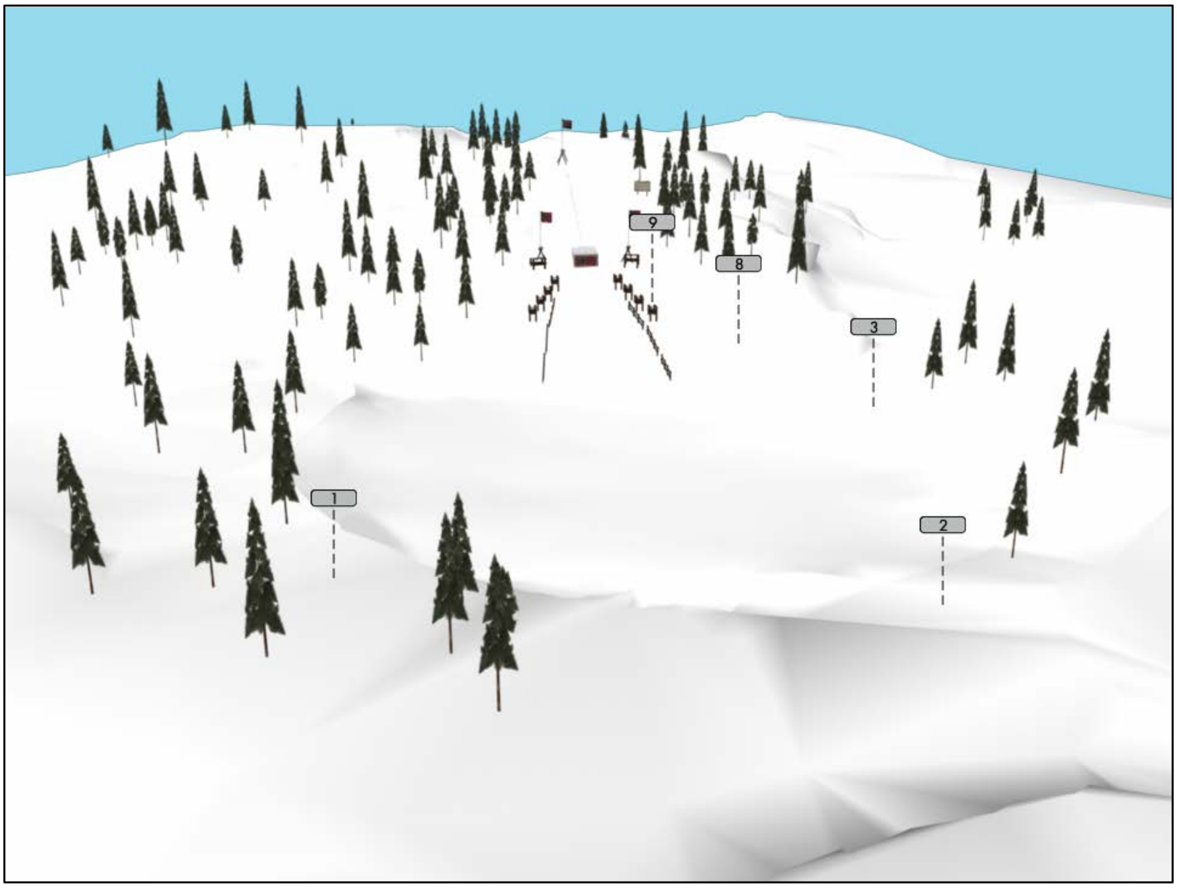
5: Name – “Museum” - http://minus.im/museum.html

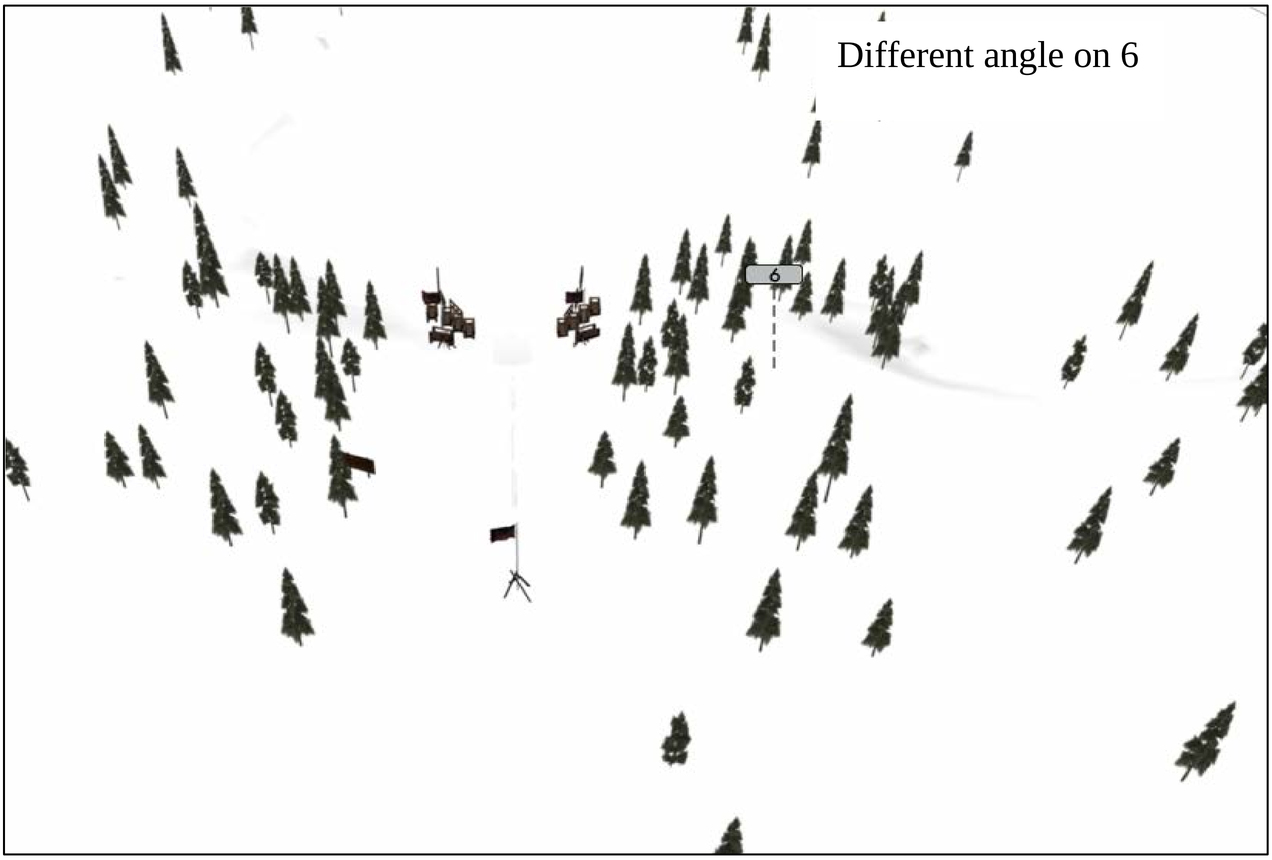
6: Name – “Equipment 1880-1930” - http://minus.im/equipment1880.html

7: Name – “Hill Development” - http://minus.im/profiles.html

8: Name – “Records” - http://minus.im/rec.html

9: Name – “Kings” - http://minus.im/kings.html





Different angle on 6

1952-Bakken

1: Name – “1952” - http://minus.im/1952.html

2: Name – “Weather” - http://minus.im/weather.html

3: Name – “Hill Description” - http://minus.im/hill.html

4: Name – “The Jump” - http://minus.im/inrun.html

5: Name – “Olympics 1952” (video) - http://www.youtube.com/embed/Y-xGrm4AV04

6: Name – “Style & Distance” - http://minus.im/style.html

7: Name – “INFO” - http://minus.im/word.html

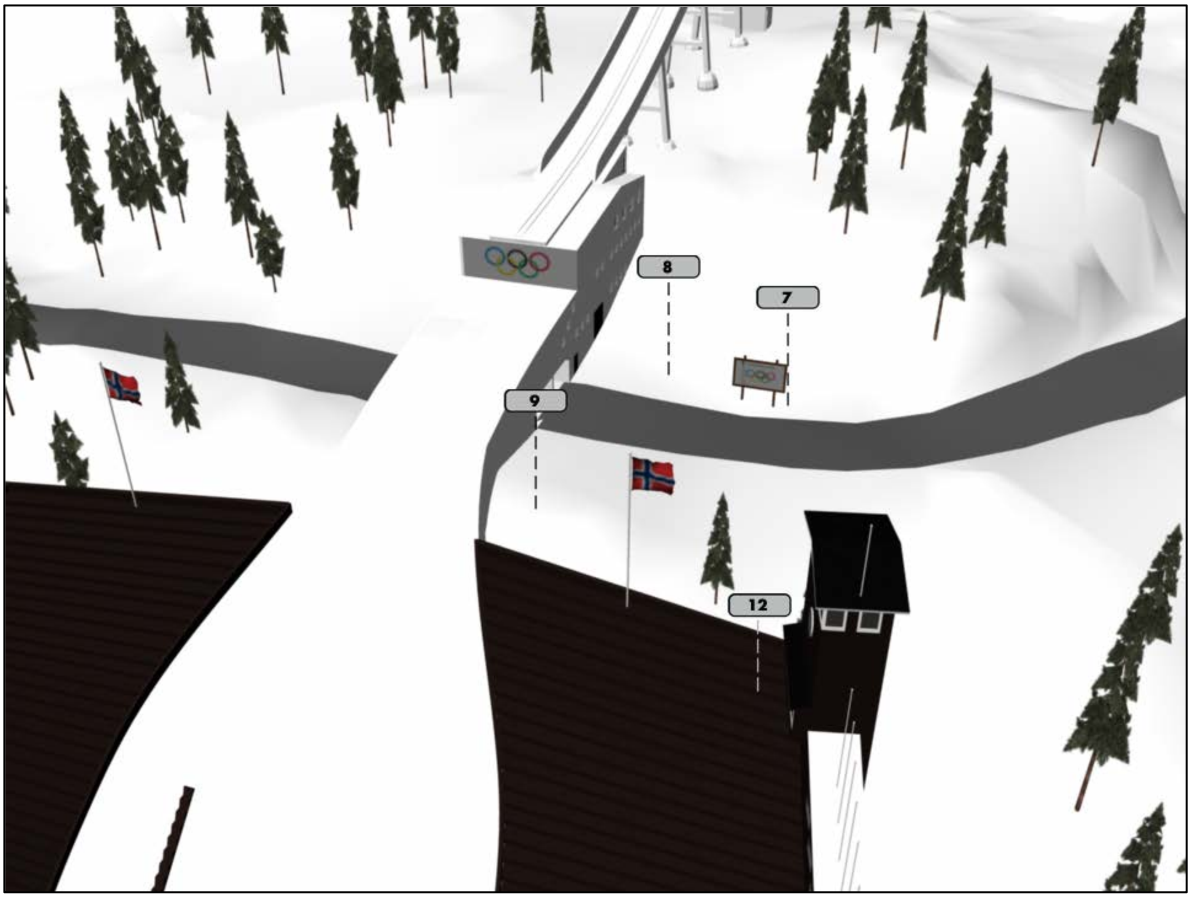
8: Name – “Museum” - http://minus.im/museum.html

9: Name – “Results” - http://minus.im/res1952.html

10: Name – “Equipment 1950’s” - http://minus.im/equipment1950.html

11: Name – “Technique” (video) - http://www.youtube.com/embed/pUk3tXDE7CY

12: Name – “Kings” - http://minus.im/kings.html



1982-Bakken

1: Name – “1982” - http://minus.im/1982.html

2: Name – “Weather” - http://minus.im/weather.html

3: Name – “Hill Description” - http://minus.im/hill.html

4: Name – “The Jump” - http://minus.im/inrun.html

5: Name – “FIS WC 1982” (video) - http://www.youtube.com/embed/YQtVQ0MbvJQ

6: Name – “Style & Distance” - http://minus.im/style.html

7: Name – “INFO” - http://minus.im/word.html

8: Name – “Museum” - http://minus.im/museum.html

9: Name – “Results” - http://minus.im/res1982.html

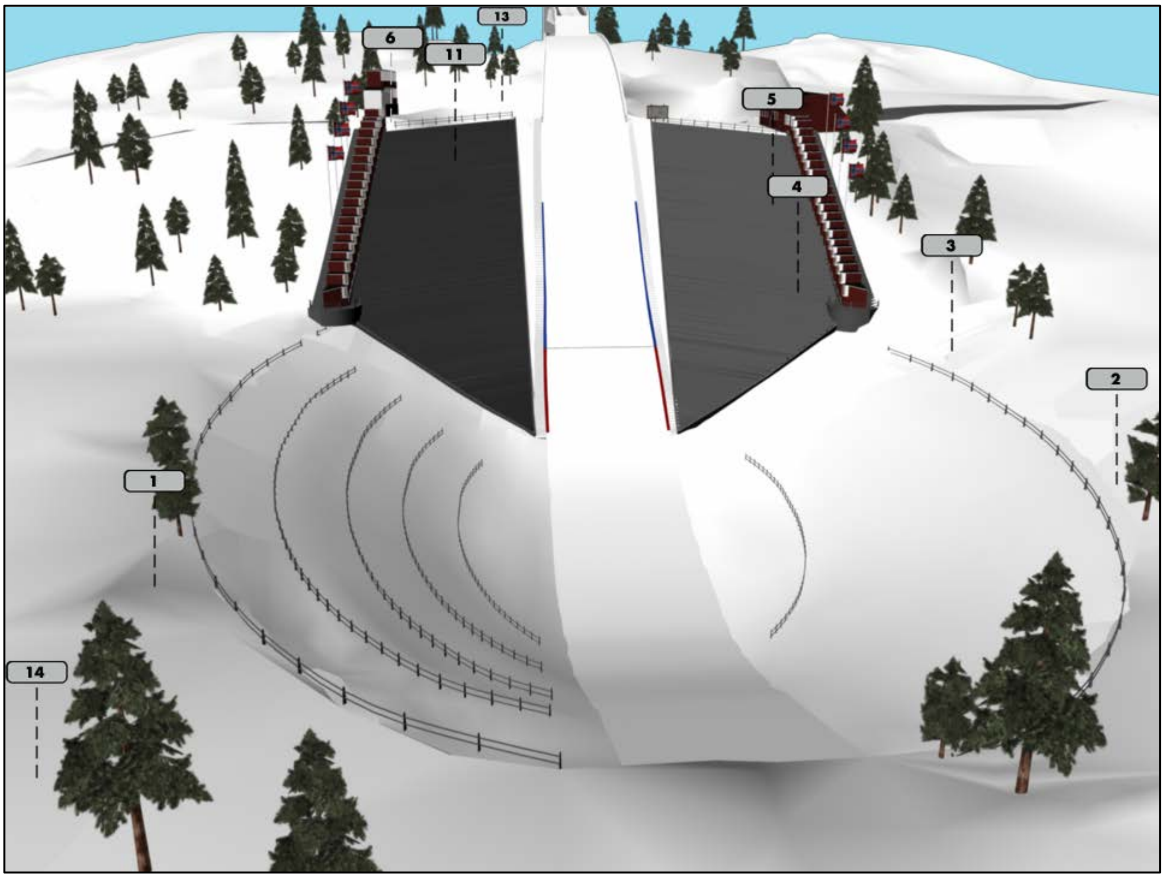
10: Name – “Diamond” - http://minus.im/diamond.html

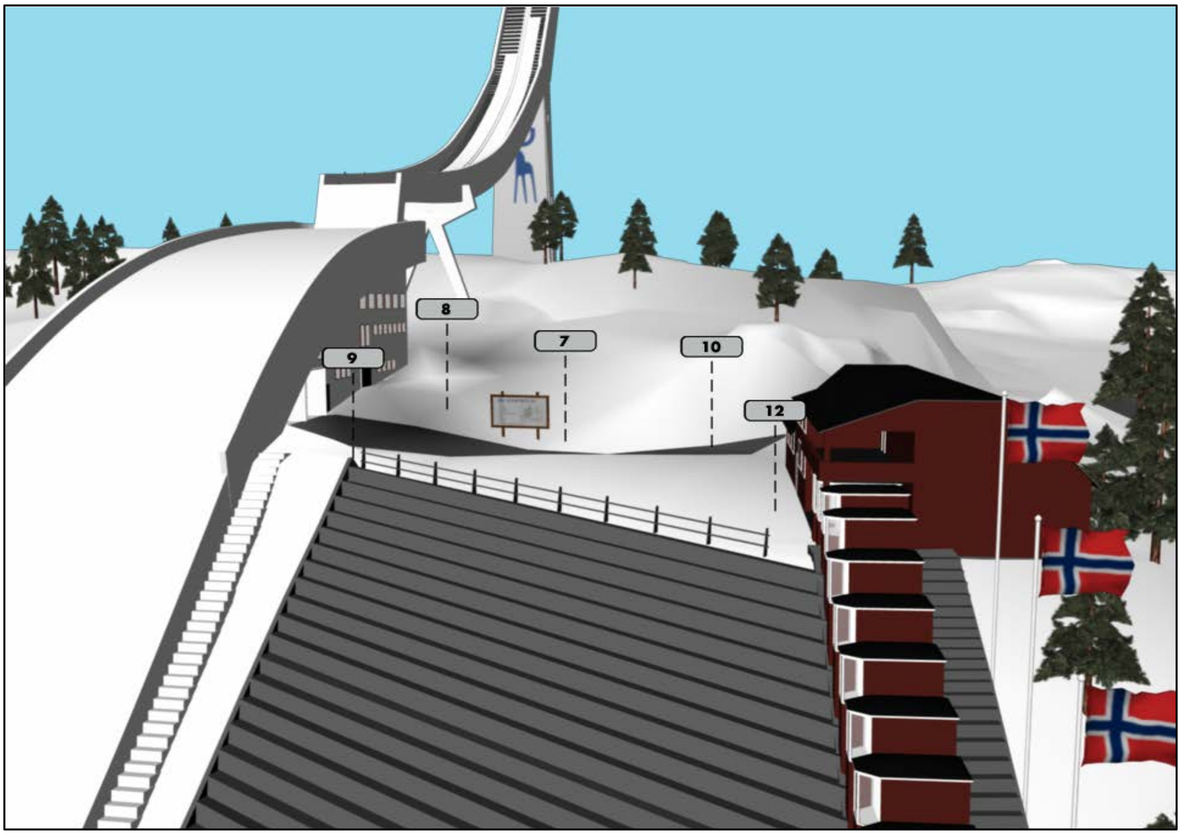
11: Name – “Technique” (video) - http://www.youtube.com/embed/pUk3tXDE7CY

12: Name – “Kings” - http://minus.im/kings.html

13: Name – “Hills” - http://minus.im/types.html

14: Name – “Mascot” (video) - http://www.youtube.com/embed/6Iq-7gxGFIw





2011-Bakken (Menu)

1: Name – "2011" - http://minus.im/2011.html

2: Name – "Aerodynamics" - http://minus.im/aero.html

3: Name – "Results 2011" - http://minus.im/res2011.html

4: Name – "Equipment 2011" - http://minus.im/equipment.html

5: Name – "Stats 2011" - http://minus.im/stats.html

6: Name – "Map" - http://minus.im/map.html

Videos:

5: Name – "World Championships 2011" (video) - http://www.youtube.com/embed/g7rADqNEbwU

6: Name – "Hill Record" (video) - http://www.youtube.com/embed/KC3cIQNoijk

7: Name – "Architect" (video) - http://www.youtube.com/embed/sj7b_siotlI

8: Name – "Helmet Cam" (video) - http://www.youtube.com/embed/rhzKZBZSr8k