CHALMERS UNIVERSITY OF TECHNOLOGY | UNIVERSITY OF GOTHENBURG

Rendering the Unseen

Utilizing Visualization for Establishing Key Factors for Understandability of Orienteering on TV

Master's thesis in Computer science and engineering

OLIWER LUNDBERG

Department of Computer Science and Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
UNIVERSITY OF GOTHENBURG
Gothenburg, Sweden 2025

Master's thesis 2025

A Chalmers University of Technology Master's Thesis

Establishing Key Factors for Understandability Improvement

OLIWER LUNDBERG

UNIVERSITY OF GOTHENBURG

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Computer Science and Engineering
Chalmers University of Technology
University of Gothenburg
Gothenburg, Sweden 2025

A Chalmers University of Technology Master's Thesis
OLIWER LUNDBERG

Supervisor: Josef Wideström, Department
Advisor: Henrik Eliasson and Per Frost, International Orienteering Federation
Examiner: Staffan Björk, Department

Master's Thesis 2025
Department of Computer Science and Engineering
Chalmers University of Technology and University of Gothenburg
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Cover: Final design of the thesis, a digital twin of the forests of Idre as seen in figure 5.6.

Typeset in LaTeX
Gothenburg, Sweden 2025

A Chalmers University of Technology Master's Thesis
OLIWER LUNDBERG
Department of Computer Science and Engineering
Chalmers University of Technology and University of Gothenburg

Abstract

Orienteering broadcasts have lately been in the forefront of taking use of different mediums to create exciting broadcasts. But with a large, remote playing fields compared to other sports it suffers from its consequences. With only small fractions of orienteering races being caught on camera, there's room for improvement. GPS-transmitters and their corresponding maps have been used in the same way for years. By visualizing all these in more comprehensible ways, understandability of the sport can be improved.

Through a rigorous design process this thesis has explored the area. Through research of the problem area, prototyping, evaluation and iteration a solution has been developed. A digital twin of a forest and a three dimensional orienteering map is the result. These have showed to improve both the excitement and intuitiveness of the broadcast.

Further, key factors have been define to establish these kinds of results. Based on the findings of evaluation methods in the thesis, the factors describes important ideas to take notice of with understandability in mind.

Keywords: Computer, science, computer science, engineering, project, thesis, visualization.

Acknowledgements

Throughout this thesis, the help of the International Orienteering Federation has been very important. I would very much want to thank Henrik Eliasson and Per Frost for the enthusiasm when it comes to bringing new, exciting things to orienteering broadcasts.

Further I would like to thank my supervisor Josef Wideström. The positivity for this visualisation project has been very appriciated and motivating. Through feedback and ideas, I have received the help needed for development.

Lastly I would like to thank the participants of the user studies. With great input comes great design, which has been clear to me through the final stages of my school years.

Oliwer Lundberg, Gothenburg, 2025-09-15

Contents

List of Figures

List of Tables

1

Introduction

TV production is an area which traditionally uses filmed material to broadcast to the audience. But, with the rise of the 3D industry it is now possible to create whatever the imagination can think of using computers to generate images. The combination of the two can be a powerful tool to tell stories. The technologies can be utilized for metrological news broadcasting showing different types of weather [1], to create special effects for action movies or to create animations for sport events to increase the viewers understanding of what they are looking at.

Figure 1.1: Visualization used within metrological TV broadcasting.

Visualization for sports has been around a long time. Different methods have been used to visually differentiate the teams for sport spectators. Distinct colors of shirts, individual numbers for players tell the audience who theyre watching. Special types of playing fields with symbols and lines break up these to represent rules of the sport. More lately, computer visualization has been added to serve as an aid for both the expert and non-expert viewer [2].

Popular TV sports all have a common denominator: they are performed in an arena that can easily be filmed by cameras. Football, baseball, cricket and tennis all take place on an open field where the audience can see the players and what they are doing. The cameras can rather easily follow the players every move, without interruption. These are very linear happening of events, where different camera angles (or perhaps commercial breaks) is the biggest interruption in the broadcast.

Sports with another type of playing field has to face challenges when it comes to TV broadcasting. An example is cross country skiing, which is a popular TV sport in Sweden. With a large competition area the athletes can travel long distances in a race. In some cases, the athletes ski around a closed loop with TV cameras placed on specific checkpoints where the audience can see the athletes and compare their split times. In other cases the skiers travel from point A to B, covering up to 100 kilometers. Through snowmobiles, helicopters and drones the audience can follow the athletes all the way of the race. Since they ski on a set course the production can plan and have different types of cameras for most sections of a course.

Orienteering is a sport most people have come in contact with from school. Most of us have tried it, willingly or not. With orienteering becoming a more popular TV sport, the broadcasting needs to evolve with it (Mattson, 2023). The Swedish orienteering federation has around 83 000 members (Svensk Orientering, n.d.), while one broadcast can reach up to 500 000 people according to Mattson's article. This could mean that a big part of the viewers at most have basic understanding of orienteering.

Sweden, Norway and Finland are countries with national productions of different orienteering events. Orienteering has some similarities with cross country skiing when it comes to broadcasting. Cameras can be put on different checkpoints in the forest, where the audience can have a brief look at the runners. However, with an even larger and more remote playing field, orienteering production faces new challenges.

The very essence of orienteering is finding checkpoints in unknown terrain. Hence, different forests are used for the broad-casted events. Orienteering does not have a preplanned route for the athletes. The orienteer choose how to navigate, to try to find the fastest way possible. To see the action from the forest, running camera men are used. This gives the audience a runners point-of-view, providing a look into what they are experiencing during a race. Further, drones have been introduced to follow the runners during exciting sequences in the forest. But, these complex, unknown competition areas creates problems. Helicopters can not see the runners through the thick foliage. Due to the vast scale, cameras can only record a small portion of the races. For a long distance of up to 2 hours, only a fraction of the action is shown to the viewers.

To compensate, orienteering broadcasts uses GPS trackers on the runners to see their whereabouts. The runners are visualized on a orienteering map, to show a 2D image of where on a map athletes are and what choices or mistakes they have made. For an experienced orienteer, these maps are easily understood. But with an audience where the main part is not active orienteers, the understanding of an orienteering map will be low. Here arises an interesting area for improvement, to better explain what the audience is seeing. To fill up the gaps between the fractions of an orienteering course that can be seen through cameras, could possibly make the broadcast more exciting and easily understandable.

As of now, orienteering broadcasts use a couple of cameras to show the runners from specific spots in the forest. But, these camera shots represent only a small fraction of an orienteering course. GPS-transmitters are further used to show the runners on the other parts of the course. These are shown on a normal orienteering map. But, for an audience with only a basic understanding of orienteering, this could be hard to understand. Here, 3D visualisation can be used to increase the understandability of the content. Hence, the viewer can understand what theyre looking at and receive a more interesting viewing experience.

For an interaction designer, this area is interesting since it will involve designing a type of 3D interface for the end user to see. This interface can be tested on different types of viewers, from the novice without any orienteering knowledge to the experienced expert. By analyzing the input, the design can be further developed to increase the understanding for the viewer. This could also lead to new knowledge around what is important for the viewer when it comes to looking at orienteering on TV. The semantics of the built world can be examined. What is best for understanding, a clearly fake world or an ultra-realistic one? Storytelling is also an interesting area for the interaction designer. Do we want to convey the feeling of actually running in the forest, with branches hitting your face and mud flying around you with every step? Or should the viewer be watching from a birds-eye-view where they can see a comparison between different runners in real-time?

1.1 Research Aim

The aim of this Master Thesis will be exploring the area of 3D for the sport orienteering. Being a rather new TV sport, it is in the forefront of broadcasting in some aspects. Using GPS transmitters and drones with cameras provides a great production of the sport. But with the problem of having a extremely large and remote playing field, there is room for improvement. Big parts of the competitions can not be filmed, since the runners are out in the forests moving fast in non-predetermined routes. Due to this, the possibility of using 3D visualization to recreate parts of these happenings will be explored.

1.2 Research Question

With the aim of exploring the TV broadcasts for orienteering sports and seeing what possible solutions there are for improvement using 3D visualization, the research question has been formalized as following:

What key factors are there for making orienteering broadcasts more comprehensible, using 3D visualization?

1.3 Background

In the year of 2000, the Hawk-Eye computer vision system was introduced. This tracking system allowed for 3D tracking different type of sporting events. The coordinates of a tennis or cricket ball could be tracked using multiple cameras over an arena. This could be used to visualise the path of a ball and help to make decisions in the games. Firstly, this helps the sport to become more fair. Human error can be removed, as seeing where a tennis ball lands can be quite difficult. Secondly, the visualisation of the ball contributes to helping the audience understand how close the ball was from in or out for example. Even the non-experienced viewer can understand how small the margins are from winner and loser with these kinds of visualizations [3].

The technology is used in a lot of different fields nowadays. In tennis it is used to rule whether a ball is in or out. The player can call for the technology to be used when they suspect a referee call might be wrong. Within a couple of millimeters, the technology can determine if a ball touched the white lines, or if it was out. Further, this can be visualized so the audience, in the arena and on TV, can see exactly how close the ball was from another call. This contributes to making the game more fair and more enjoyable for the viewer [4].

Football uses a similar technology that has become popular in later years. The VAR technology is used for different purposes in the sport. The main reason is to check different situations though different camera angles. This helps to make the right call, when the referee cant determine in the split second it happened. This has helped improving the rightness of calls made on the field [5]. Further, it gives the viewers an insight in the sports, where they can see what the right call in the situation was. They can see how small the margins are in different situations, and different rules can be visualized on top of this. Graphics can be put on top of footage, where a red line can show the viewer how close an off-side call was from on-side for example.

This type of visualizations is another addition with these technologies, on top of the rightness of the calls. They bring another dimension to the sports, where the audience can be shown content that an ordinary camera cannot show.

In the 2024 Olympic Games, 3D visualization was used in table tennis to bring another dimension to the broadcasts. In the breaks between sets, data from the points would be visualized. The ball had been tracked through 4 different cameras to create 3D animations. The audience could see where on the table the players had been placing the ball most frequently. This showed new data, helping understanding how the players where playing the game. Further, other data like ball speed, spin and trajectory could be tracked and visualised. All these help the audience understand the game and what players are doing to beat their opponent. Through computer generated images, another dimension is brought to the sport, trying to make it more exciting and understandable.

1.4 Research Area and Problem

The research problem that will be focused on is bridging the gap between an orienteering map and reality. Taking use of technology, sports can be made both more fair for the athlete and exciting for the audience.

As of the state of orienteering broadcasts, the problem lies in understandability and enjoyment. Now, the viewers are presented with a 2D map on the broadcasts. With the help of 3D animations of both environments and runners, the project aims to create a more understandable and more exciting experience for the viewer.

By building environments based on laser-data from the real world, these replicas can be used as virtual forests to re-create the actions of orienteering runners. This will further be done by exploring the possibility of using GPS-data to create real-time animations of characters, based on the coordinates of runners out in the forest.

2

Theory

The theory section describes frameworks that the research will take into consideration. This includes both the problem statement and the design process itself. Areas as visual semiotics, user experience, visual semiotics and 3D visualization for sports are described.

2.1 Research Through Design

As a master thesis project within the field of interaction design, this work will mainly perform its research through design. The design created will act as a prototype which can be tested, iterated to then be tested and iterated more times. What can be then expected from research derived from design? Gaver [6] argues that theory deduced from design research is preliminary and ambitious, rather than being confirmable. From this project we can then expect a result that here and now can contribute to the field of 3D visualization within sports. The findings will not be a clear true or false to a problem area, but rather an aspiring addition to the field and researcher who would like to further explore the design area.

2.2 Wicked Problems

The notion that research through design should provide a solution that is not necessarily right or wrong, leads to the idea of Wicked Problems. The research area for this project is one of the sort. Buchanan [7] talks about Wicked problems and the rules that Rittel and Webber defined in 1972 around the specific type of problems: *For every wicked problem there is always more than one possible explanation, with explanations depending on the Weltanschauung of the designer.* This description of a Wicked problem does seem important to take into account. The Weltanschauung, or world-view, of the designer will affect the explanation that he or she finds to the problem. Hence, the designer has to be aware of how they are affecting the design. They have to take into account both the positive and negative contribution they have on the solution, and perhaps try to minimize the latter. The designer is responsible for their own actions, and according to Rittel and Webber [8]: *The wicked problem solver has no right to be wrong.*

2.3 Graphical Interfaces

The aim of this project is creating visualizations of orienteering. This type of design can have a lot of similiarities with designing graphical interfaces for a user. The same methods with using different type of evaluation methods and prototyping will be used. Since TV is usually a non-interactive media, the interface designed will only been seen by the audience. Since they can not make choices in what they are seeing, this will put even more weight on the chosen images for the viewer. What the viewer want and need to see has to be explored to design the optimal viewing experience.

Visual interface design theory can be used to apply theory on the design work made. Alan Coopers book about the area provides important elements for designing a visual interfaces [9]. He talks about leading users through the visual hierarchy. By understanding what which parts of an interface are the most important for the user to understand quickly, information could be prioritized. More important information can then be presented in a larger and more contrasted way to background, for example.

Drawing attention to important events is another principle. By actively presenting important happenings on-screen to the user, they can gain information in an effective way. Doing this, without drawing attention from other important things is a balance that can be hard to achieve.

For designing a graphical visual interface, principles for effective communication are a foundation to design upon on. Visual consistency is one important aspect that both Marcus [10] and Cooper [9] talks about. This implies a consistent look and feel throughout a product. To keep an internal consistency within the design is key for the user to learn the interface. Productivity can hence be increased and errors can be reduced.

2.4 User Experience

The application of User Experience theory will be an important part of the project for designing an end product that could please the end users wants and needs. Through user input, design choices can be made and new ideas can arise that were otherwise not thought about.

By creating an experience for the viewer, which speaks to their emotions, the enjoyment and excitement could be impacted. Hassenzahl and Tractinsky [11] argues that fulfillment of universal psychological needs play an explicit part here. Complex emotions could all be evaluated through a common denominator, pleasure and pain. An evaluation like this could be important for creating behaviors or sources of happiness connected to an experience. They further argue that the pleasantness of an experience can be linked to the fulfillment of psychological needs. Hassenzahls own look at positive experiences through technology showed stimulation, competence and popularity to be conspicuous sources for origins of pleasure [12].

If an experience can be positively impacted through stimulation of basic psychological needs, this thesis can take advantage of that. For example, competence was found to improve the positive experience. Understandability, being the focus of this project, can be improved with the competence of the viewer being improved. By helping the viewer understand what they are seeing on TV, their competence of the area can increase. Both the positive experience of the broadcast and the understandability of it be enhanced simultaneously.

2.5 Visual Semiotics

Visual semiotics is the theoretical study of visual signs and their relation to each other. This is an interesting field for this thesis, where meaning of images can be researched. The communication of images can be tested to see if the viewer is given signs that can be interpreted correctly.

A common idea within visual semiotics is that conceptual ideas can not be directly communicated to a person. The idea is that visual signs from an image is interpreted by a viewer within a context. The connection between an object, its sign and interpreter is described in Charles Sander Pierces model of semiotics as seen in figure 2.1. He describes a mutual dependancy between the three. This triad is summed up by Wideström as the sign standing *for* the object *to* the interpretant [13].

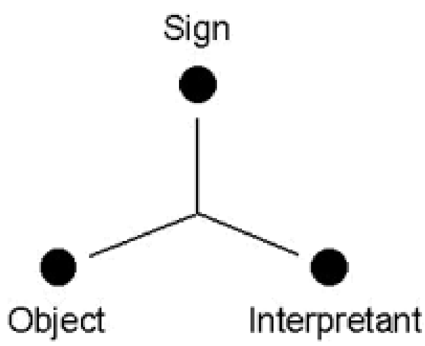


Figure 2.1: The triad of semiotics, by Pierce.

The same model describes three different types of signs. The first is *Icon* which connects to the object through similarity. The second is *symbol* which is connected through norms or habit while the third, *index* refers to the object through factual connections.

With orienteering maps being some form of communication shown to an audience with or without experience, these different signs has to be interpreted by the viewer. By studying how these signs are interpreted by the viewer the findings could be used to improve the understandability of the images.

Orienteering maps uses indices that points to factual connections. Hence, the viewer needs experience to make the connections to the physical world. Without experience of orienteering, these connection might be very hard to make. What does a black dot on a map mean? What does a brown curve represent? These signs given without any context or without experience might be useless to a viewer. Hence, providing further 3D visualizations together with an orienteering map could help the viewer in a positive way.

2.6 3D Visualization

The chosen media for this project is 3D visualization. With an interest and belief that it is a great way of producing visual content for TV this will be a key part of the project. Using this media to create compelling visuals that can communicate concepts in a new way compared to how it is done now is ultimately the aim.

3D visualization can help improve understandability of images. For semantically rich data, which orienteering maps could be described as, three dimensions could be beneficial. Teyseyre and Campo [14] describes that 3D can aid the human perception. Aesthetically enjoyable visuals can help improve appeal and intuitiveness for the design. More information can extradited from the image, while the extra dimension gives better spatial perception due to depth cues. Further, a more natural representation of the world can be created, compared to 2D images.

2.7 Visualization within Sports

Recreation of sport events using 3D is an area widely explored. Cornelius Malerczyk [15] discusses 3D reconstruction, camera calibration and motion estimation for visualization of sports on TV.

2.7.1 Photogrammetry

To create replicas of the real world, from TV footage, they suggest the use of *Photogrammetry. Photogrammetry* is defined as *the science of obtaining reliable information about the properties of surfaces and objects without physical contact with the objects, and of measuring and interpreting this information* [16]. By taking use of multi-view pictures from cameras filming events, the recreation of 3D environments can be done. The 3D environment can then be used for visualization of sport events.

2.7.2 Gaussian Splatting

More recently, a technology called *3D Gaussian Splatting* have been on the rise. Like *Photogrammetry*, the technique aims to recreate physical spaces using different inputs. Unlike more traditional methods like *Neural Radiance Fields*, or *NERFs*, that can generate scene geometry the *Gaussian Splatting* operates differently [17]. By creating an approximation of a space using Gaussian ellipsoids, real-time rendering (around 30 FPS) can be achieved. This includes consumer-type graphics processing units. While the technique can result in realistic results suitable for real-time cases, the end result might not yet be geometrically as precise as the traditional methods.

2.7.3 Pose Estimation

Schenk [16] further dives into 3D pose estimation for reconstruction of athlete body movements on screen. Using video from at least two different angles, the images are processed through several computer vision technologies seen in figure 2.2. The different steps are used to output body animations onto 3D characters.

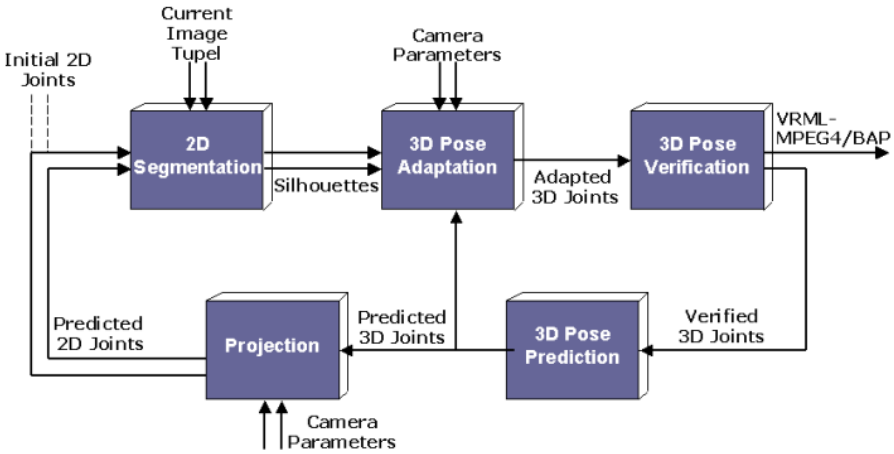


Figure 2.2: Computer Vision Technologies applied for 3D Pose Estimation.

2.7.4 Sport Analysis in 2D

The earlier graphics for sports analysis takes use of 2D elements for analysis, which are still used today. More recent ones applies calibrated camera images to be able to apply these grahpics on top of recorded sequences.

2.7.4.1 Calibrated Camera Images

Through mechanical sensors mounted on moving cameras and lens, data around camera movement and zoom can be gathered. Calibrating graphics to this data enables 2D overlays to be correctly placed on moving images. Overlays like off-side lines for soccer or time comparisons for swimming take use of knowledge of playing field geometry to place these graphics correctly [18].

2.7.5 Sport Analysis in 3D

For 3D analysis the same principle used in 2D can be applied for approximation. By calculation of 3D positions of athletes, assumptions can be used for 3D positions. Feet being placed on planar ground is a type of assumption. This allows for placement of characters in a 3D environment, or just simple plane geometries with cut-outs of athletes as an image plane, as showed by Thomas [18]. Further views than what is being recorded by a normal camera can hence be displayed to the viewer. This can help explain sport scenarios, showing the viewpoint of a football linesman during offside, or an orienteering athlete during a mistake. There are some difficulties surrounding this approach. With use of a single camera, players are caught from one angle. The virtual camera will then be limited in where the players can be shown from. Hence, multi-camera systems are used widely for tracking of tennis balls for example.

3

Methods

The third chapter dives into methods of this interaction design project. Possible methods suitable for analyzing of the problem, prototyping, design work and evaluation are described here.

3.1 The UX Lifecycle

The UX Lifecycle template decribes the circle-like behaviour of UX design. The four fundamental stages of this process can be focused and iterated on to make design choices based on rigorous methods. By analyzing the field, informed first idea generation can take place. The problem areas can arise where understandability needs to be improved. By focusing on these fields, a first step towards a solution can be taken. Using prototyping, the early solution ideas can begin to form. Using these prototypes for evaluation with stakeholders will be key for improvement. With evaluation, new areas of interest can arise. Further iteration on the design can made using the input from users. By later evaluation, a final design can be set and tested to see if improvement has been achieved. The main steps of the wheel are shown in Figure 4.1 below [19].

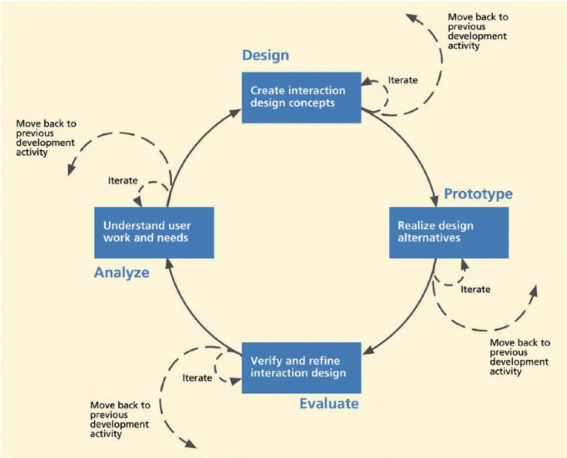


Figure 3.1: The Wheel.

3.1.1 Analyze

Analysis means to understand the user group and what needs are important for them. For this project, the user is the audience of the TV broadcast. Their interaction will hence be strictly visual. The audience will not be able to affect what they see on screen, which puts high demands on the content created. Issues like being too hard to understand or even boring could lead to confusion or that the audience doesnt want to watch the broadcast. To find a solution that stimulates the needs of the viewer and contributes to a more comprehensible broadcast will be very important.

3.1.2 Design

Designing visualizations for will consist of creating ideas of virtual maps and forests. Different prototypes will be created to be able to determine how visualization of a forest can be done best. Simple worlds with basic shapes for trees and stones can be compared to ultra-realistic worlds to evaluate what the viewer enjoys and understands the most.

In addition to the forest, the possibilities are endless within visualization. To decide what the audience is shown will be part of the design phase. What data can be useful to the user, for example how big of mistake a runner made or how many meters a route choice is compared to another. These design choices will be important, to give interesting and coherent information to the viewer.

Further, characters might be needed to show the athletes in the virtual world. These could reflect same level of realism that the virtual forest does. But, testing different designs of characters could also be useful. Perhaps, different levels of realism is optimal. If the end solution consist of an ultra-realistic forest, a close to human character could spark the Uncanny Valley Effect. This means that the 3D character which try to resemble humans visually and in movements, could lead to negative effects on the beholder. Studies have shown that audiences are more sensitive to flaws of the realistic characters compared to stylized ones [20]. Wether to take a leap over the uncanny valley or choosing to stay on the safe and unrealistic side of it will be an interesting area to discover.

3.1.3 Prototype

Prototyping will be focused on digital ones. Since this solution is supposed to be shown on a TV broadcast, a physical prototype seems less useful. To focus on creating rigid prototypes with the same level of fidelity will be important for the next step of evaluating. This step will be very much parallel with the designing. Sketches can be made of the virtual world, but lower fidelity prototypes are also possible to create as digital ones. Hence, the designing and the prototyping will happen hand in hand.

3.1.4 Evaluation

When different designs have been created and prototyped, they can be evaluated on different levels. Using both rapid evaluation to take smaller design choices and meticulous methods will lead to confirmation of design choices as well as new ideas and problems for iteration. Rapid evaluation include design briefs and discussion with the supervisor and the company involved. These are more expert users that have some insight in the project from before. Hence, taking into account the biggest user group will be important here. The in-experienced orienteer without insight in this project will be the most important one for evaluation. Early design testing simulating how the audience would interact with this type of content can lead to early insight in important needs and design ideas.

By using more meticulous evaluation, the designs can be tested for data collection and analysis. Since this is a solo project, the evaluation teams consist of 1 person. Data collection during an evaluation could be more difficult due to this, which makes planning of these sessions very important.

The prototypes will be tested on the subjects as evaluation. Since these are visual and most likely virtual prototypes of different fidelity, these can be tested close to the normal use case, which is in a broadcast setting. The subjects can be told that they are about to watch a TV broadcasts of orienteering. Here different type of data can be collected from the evaluation.

3.2 Double Diamond Design Process

Another typical visualisation of the the design process is the double diamond [21]. This design process is defined by four phases, shown in figure 3.2.

The discover phase aims to explore the nature of the design problem. By expanding in the area and searching wide for different reasons and areas of interest, new insights can be gathered that was not thought of in the beginning.

When areas of interest has been found, these can be defined and narrowed down to a focus area. A problem definiton can be set, as to what problem the project aims to design for.

When a problem definiton has been set, the scope can once again be broadened. By developing potential solutions around the problem definition, the design space can be explored to a broad extent. This minimizes missing possible solutions beneficial for the user. Solutions can be tested and evaluated for further development.

Through prototyping, evaluation and data analysis a solution can be chosen. The delivery phase consist of reifining the prototype to deliver a final design. Through input from users the designer can make informed choices on where to take the final design.

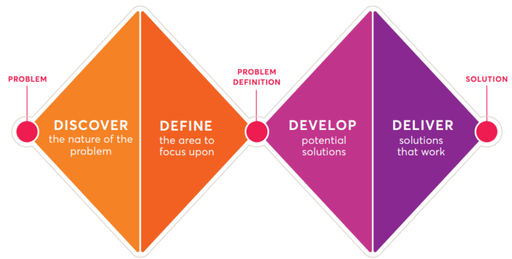


Figure 3.2: Design Process visualized in the Double Diamond.

3.3 Quantitative Data Collection

Since there is no physical interaction where the subjects can make choices in the prototype, some types of quantitative can not be collected. Data like number of errors or time of tasks cant be measured. But other types of quantitative methods could be used for the interviewees to give their opinion.

With orienteering broadcasts having a large audience with a vast variety of viewers, the data collection could benefit from methods suitable for large data collection. Taking use of methods like surveys that could be distributed to a large number of people, it could gather a dataset that covers more people opinions and a bigger part of the viewer group compare to other methods. This would result in a more useful input for designing.

As decribed by Nardi [22], surveys can be a less costly method to reach larger audiences. As for a TV broadcast with viewers from a variety of countries and backgrounds, this would suit the case. Further, the big data set that could be collected through surveys could assure wider coverage of user groups than for some qualitative methods.

Negatives with quantitative data collection starts in the answers of the subjects. What they answer and what they actually do, can be two different things. By not being able to study the subject first-hand, their actions can not be taken into consideration. Further, probing into different areas of interest can be performed. If the subjects bring up something that would need further questions to decipher, the possibility is not there.

3.4 Qualitative Data Collection

For qualitative data, which could be the most interesting regarding this project, the collection will be more difficult with a team of one. To both facilitate the evaluation and collect answers from the subjects is a big task. Recording of sessions might be a solution, so data collection can happen afterwards. Hence, the subject can receive full attention during the session. Interviews during or after the prototypes has been shown would be a good option here, where semi-structured template of question is prepared. This would leave room for new questions to arise [23].

To create interviews that can extract rich data, the semi-structured interviews will be important. This will help understanding what the subjects are experiencing, feeling and thinking. Using open-ended questions and probing for further information will be used to gather these thick inputs from the users that might be missed otherwise [23] [24].

To create open-ended questionnaires can be difficult. The open-ended responses is also a type of data that is harder to decode. The interviews can also be more time consuming for the project team.

Focus groups would also be a interesting form of evaluation. These designs will have different type of stakeholders. The audience mainly consist of non-expert viewers with little experience of orienteering. One part of the user group is expert viewers that understand everything they see on screen easily. Both these groups can give good insight in what the different people need and where they meet. It is further a good way of collecting rich, quantitative data [25].

Another interesting group is the commentators. The ones handling the storytelling of the whole broadcast needs to be able to mediate what the viewers are being shown. The content created for this project needs to help these professionals with their job.

Different focus groups with all these user groups could hence give a lot of data regarding the prototypes.

3.5 Thematic Analysis

Thematic analysis can be used to analyze quantitative data. Since this kind of data is not numbers or easily measured error faults, this method can tell a rich story about the data. Different levels of themes will be interesting for this project. Semantic themes will be important for extracting surface level themes from the test subjects. Here, the direct meaning of what has been said or written will be examined. This is also an effective way of organizing data in themes, which can be used for further evaluation. By identifying these semantic themes, they can be put for interpretation by the evaluator. Hypothesising deeper meaning below the surface level can form deeper meaning to the rich data. What a person says is sometimes not how they actually feel, which this method could perhaps help with [26].

Through the step-by-step guide for performing thematic analysis seen in figure 3.3, a thematic analysis of qualitative data can be performed. By first familiarizing with the data, it is necessary to read it through actively several times. With initial thoughs about the data from the collection itself, possible meanings and patterns can start to occur. With verbal data from recorded interviews for example, the data has to be transcribed for thematic analysis to be possible. This is also a good starting point for familiarizing since the data can be processed at the same time.

Phase	Description of the process
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Figure 3.3: Step-by-step guide for Thematic Analysis.

By generating inital ideas of what the data might contain and mean, codes can start to form. These correspond to a semantic or latent feature witin the data. These are described by Boyatzis [27] as *the most basic segment, or element, of the raw data or information that can be assessed in a meaningful way regarding the phenomenon.* With these early codes forming ideas around the data, themes can start to emerge to the analyzer.

With the dataset coded, these can start to be sorted into possible themes. The individual codes are analysed to find common denominators within each other. When possible the codes can be combined forming themes within the data. Overarching themes can be created, as well as sub-themes within these ones.

With themes created, they need to be reviewed. Themes need data backing them up, while some might be merged into others. Dividing themes that describe to broad of an area is also possible. There should be distinct differentation between themes while the data within one should describe it meaningfully together.

Lastly, the themes can be refine and named. By catching the meaning of a theme and deciding what the data encompasses, the final themes can be set. The interesting areas of a theme should be presented and why.

4

Design Process

The design process of this project was based on four stages; exploration, design, prototyping and evaluation. The plan is described in this chapter, as well as the execution. Further, a re-design was made using based on the evaluation of the first prototype. Lastly, key factors for understandability are defined to address the research question.

As a starting point, Idre Fjäll has been used as the working location for this thesis. In June of 2025, a World Cup in Orienteering will be held there, and the goal is to develop a product that can be tried in the International TV broadcast at this event. This has required working with height data from the landscape of the interesting area, creating different fidelity prototypes of 3D worlds to test and finalizing a product that can be used for both pre-production and in a live-scenario. The design process is described in this chapter.

4.1 Planning

The methods used for this project will help plan out the different stages of it. Since this is a very new area, the first phase will consist of exploration. A visual time plan can be seen in Figure 5.1.

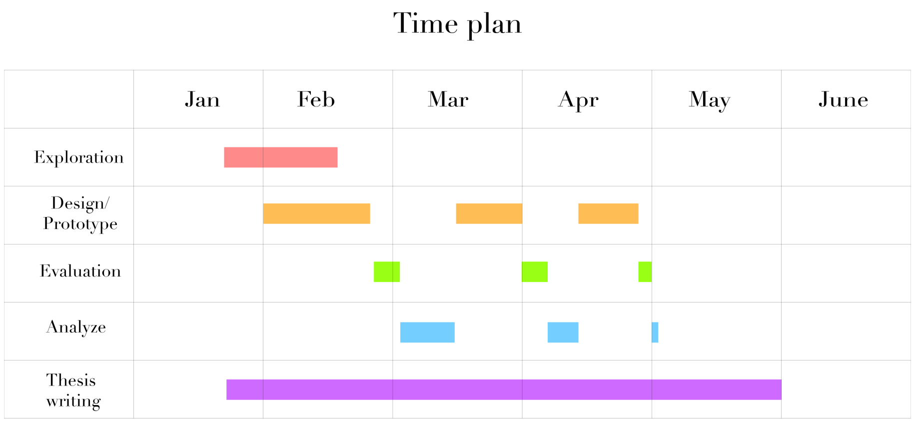


Figure 4.1: The time plan for the different stages of the project.

4.1.1 Exploration

The first part of this project is an exploration phase. To early establish what might be possible when it comes to different solutions will be important as to where the thesis will be heading. Creating 3D worlds in Unreal Engine used for orienteering broadcasts is an unexplored area for the thesis writer. By trying different options to use real-world data, like laser scanned height data of Sweden will be the first step of the exploration. To see if landscapes can be generated will be an important step in optimizing the workflow for this type of project.

The next step of the exploration phase will be regarding real-time GPS data. Orienteering broadcasts use GPS-trackers on the athletes, to show the audience where they are located on a 2D map. If this data can be transformed to a location within the 3D software, these locations could also be visualized in a 3D world. Whether this is possible is not known, and hence different methods need to be explored. Utilizing longitude and latitude coordinates inside of the game engine, and convert these into software units will be a challenge.

Converting the locations to drive animations for running characters will be another problem. The animations need to move correctly accordingly to where they are located in the world.

The re-creation of real-life worlds will be another important area. Since these animations will be shown together with footage from the actual forest athletes are in, the animations needs to look very realistic. This is also a wish from the company stakeholder, to create realistic content for the broadcasts. To explore different ways of creating authentic forests will be another exploration area. On the contrary, tests might show that unrealistic forests are a better way of visualizing this to the audience. Hence, not too much time will be spent in the beginning without testing different options first.

4.1.2 Design and Prototyping

The exploration phase will transition into a phase of early designing and prototyping. This will happen naturally with the exploration. Using these for early evaluation will be beneficial in many ways. The users can form a much better understanding of what this project is trying to create. To see a low fidelity prototype of digital forest will give a better understanding of the product compared to a paper prototype for example. Hence, the test will be closer to the viewing experience and it will give better input for design insights and improvements. With evaluation on the prototypes, iterations will be done to create a more finished product.

4.1.3 Evaluation

To evaluate the first designs will be important to be able to take design choices based on extensive research. Focus groups and interviews can be used to get input for the different user groups like audience, spectators, stakeholder company and more. Using these insights, iterations can be made to improve the solution.

Evaluation will hence happen in different stages of the project. Two evaluation sessions will be the first plan for the project. However, this could change if the results of the first ones are not satisfactory.

4.2 Ethical Considerations

Orienteering characters used in the game could be reassembling real people to give a more realistic feeling to viewers, as where they could recognize the person running in the animations. If this would be done, these runners would have to be talked to beforehand, to have permission to use their persona in this kind of way. Otherwise, a workaround could be a generic person for every animation or a man/woman for the different classes of orienteering which are split up into men/women.

GPS-data will be received from a different company working with navigation technology. Their cooperation will be needed to be able to explore this part of the project. Taking into account their policies for handling the data will also be important in the project.

4.3 Brainstorming

This project aims to explore new ways of presenting orienteering on TV, to make it more understandable and exciting for the viewer. To come up with early ideas of how this could be done, brainstorming was used. Through discussion a series of early ideas were cemented to base the design project on.

Through a teams meeting with the stakeholder company, being the International Orienteering Federation, and the thesis writer brainstorming was performed. With the research question in mind, how orienteering on TV can be made more accessible, areas of interest were first discussed. The possible areas of improvement included:

- Forest presentation. Drone shots and some running camera is shown in the forest as of now. Can the competition area, forest and course be shown in a new manner?
- Live mistakes. Mistakes are shown with GPS on map as of now, but could this be shown in a more understandable way?
- Map improvements. How can the traditional orienteering map be understandable for in-experienced viewers?

These points were deemed to be the most interesting. Since a big part of viewers do not have an orienteering background, the consensus was that parts that can be hard to understand for these viewers has to be focused on.

For all of these areas, a digital twin of the forest had to be developed. As a start of the exploration phase of this digital twin, possible usage of real-world height data was explored. Further, the possibility to create a 3D replica of the forest growing on top of the landscape would be explored.

Since these ideas of visualization for orienteering does not exist, early user tests was deemed as less useful. Without having a prototype, the possible questions to users would be very speculative. Asking user to imagine if 3D forests and maps could be useful for their understanding could be too difficult. By developing a first prototype that could be used for user tests, something visuals could be presented to the users. They could give direct feedback to how these visuals helped their understanding. While low-fidelity prototyping could have been used, like paper-prototypes or sketching, the idea of a more high-fidelity digital prototype was deemed more useful. By going for this type of prototype the explorative phase of the project could be started and progress towards a more final design could be reached quicker. The time aspect was important for this project, as the scope of creating a full digital twin was quite big. Starting off early with a 3D prototype helped the project advance quickly, leaving time for later problems arising.

4.4 Digital Terrain Model

One part of this project aims to take help of real-world data to recreate environments for orienteering. A starting point in this is finding and using height data of real places. Idre Fjäll has been used as the working location for this.

4.4.1 Lantmäteriet

Lantmäteriet is a Swedish authority that provides geodata of Sweden. The exploration of possible data that could be used started here. First, free options were considered.

Laserdata Nedladdning, skog was first tried out [28]. The download came as a .laz file which is a pointcloud from a laserscan of a landscape. When importing the file into a 3D software, it was quickly determined this was not the most useful option. This data was received as a point cloud 3D model of everything in the forest. This includes trees, bushes and every type of vegetation on the ground displayed as a model. But, there is no detail captured in the vegetation and the low fidelity will not be optimal for displaying in a TV broadcast. Hence, other options where only the ground plane of the landscape is captured was explored.

Terrain Model Download, grid 50+ is another free product Lantmäteriet is providing [28]. Its a Digital Terrain Model (DTM) which has a resolution of 50 meters. This means that each pixel in the images delivered from this product relates to a 50 times 50 meters square in the real world that has been captured. After looking at these images in a 3D software, it could be determined that a lot of smaller details will be lost in such data, where a more broad and big landscape is better for this type. For the sake of orienteering, where details such as small knolls and depressions are needed, this was too low of resolution.

Terrain Model Download was a paid option at the time of testing, which has now become open data under the license CC4.0 [29]. This DTM was the third option tested in the project. With a resolution of 1 meter, it gives a very detailed model of the terrain. This is what is usually used for orienteering maps, as a base for height contours. Small details of terrain are caught, which made it a good option as a digital terrain model. The terrain model was ordered on Lantmäteriets website [30].

When this project started, the area of interest was chosen in the SWEREF 99 referencing system [31]. During the project, Lantmäteriet have transferred to a new way of downloading the height data. Hence, the updated workflow for downloading correct area for a height-map can be accessed through Lantmäteriets website [32].

4.4.2 Merging and transforming the DTM

The DTM was delivered from Lantmäteriet in the format of GeoTIFFs. This is an image that goes from black to white, depending on the height of the landscape in the picture. To be able to use the images in Unreal Engine, they have to first be merged together and then transformed to PNG, since Unreal Engine cant handle the GeoTIFF format. This was done in the 3D software Houdini.

4.4.3 Merging height data in Houdini

Houdini has a free version that can be used for educational purposes. For this version, resolutions are limited to exports up to 720x720 pixels. Hence, a paid student version was used for this thesis. However, all the steps below can be repeated with the free version except exporting the PNG image in higher resolution.

To start off the process in Houdini, a Geometry node was created in the node box. Opening the node by double clicking inside on it, is where all the nodes were placed.

Inside of the Geometry node, right click and type *Heightfield File*. Inside the heightmap, a GeoTIFF image can be loaded. Here, the size of each image can be chosen. In the SWEREF99 system each box is 2.5 km. The size would here be 2500 since Houdini uses meters as unit. However, for this project a size of 1002 units have been used. There are a couple of reasons for that: The landscape needs to be scaled down for usage in Unreal Engine. An animation will appear quicker in this smaller landscape, and the 2.5 scale down is not too noticeable when it comes to relative scale compared to characters or objects like trees. Performance will increase, when not having to build a real-size forest. The 2 extra meters, on top of 1000, is due to the nature of GeoTIFFs. Each image have a outline of 1 pixel, which creates lines when merging them together. Hence, the landscape is made a bigger, for this line to be written over when merging. The height scale could be changed here, but for this project it will be done later in Unreal Engine. The above steps can be seen in figure 4.2.

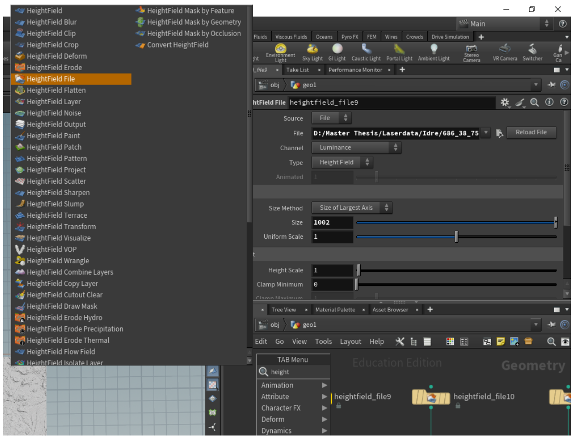


Figure 4.2: Heightfile File node inside of Houdini.

Repeat this first step of importing for every GeoTIFF in the landscape. The next step is to place the adjacent ones next to each other. By adding a *Heightfield Transform* node under every file, the files can be transformed accordingly. Using the SWEREF 99 reference system, the files in this example have been placed next to their neighbors. Choose one picture for reference, the top left in this example. Then move every adjacent image 1000 units in one direction. The figure 4.3 shows the right (or east) neighbor of the top left image moved 1000 units in Z direction. The next image right of that one will be moved 2000 units in Z direction. Further, the images that are located under (or south) of your chosen reference picture will be moved 1000 units in X direction.

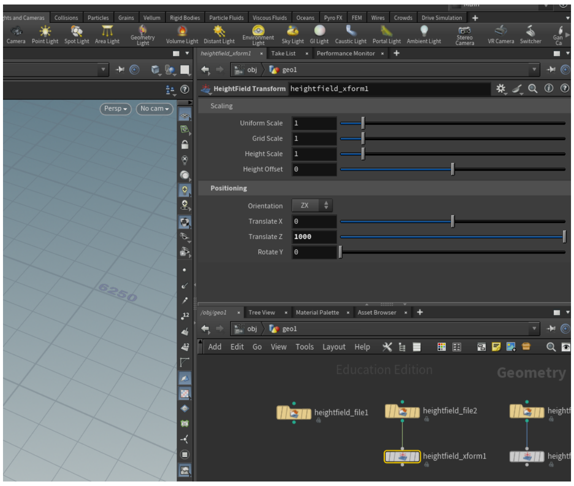


Figure 4.3: Heightfile Transform node inside of Houdini.

When all the different GeoTIFFs had been moved to the right location, these were ready to be merged to one single landscape. This was done through a *Merge* node. All the different transformed heightfield files are connected to this *Merge* node to create a merged landscape file.

Next, the landscape had to be further transformed to center the pivot. Another

Heightfield Transform node was connected to the *Merge* node. The landscape was moved 4000 units on the X axis and -2000 on the Z axis. This step was done for the following one, where all the merged height fields will be projected onto a single one. Having the center in the middle of the 3D space will come in handy inside of Unreal Engine as well.

With the landscape centered, a *Heightfield Project* node was created. Further, a new *Heightfield* node was created. Connect the new nodes as shown in figure 4.4. The setting *Grid Samples* of the *Heightfield* node is set to the image size needed for the final landscape. Using Unreal Engines technical guide for landscapes, a suitable size can be chosen [33]. For this project, both 4033 and 8129 have been used depending on the final quality needed for the landscape. For better performance, 4033 is more suitable while 8129 results in a higher fidelity landscape. Further, the size of the new, merged landscape is entered here. 5000 meters is the actual size of the combined parts, which is entered.

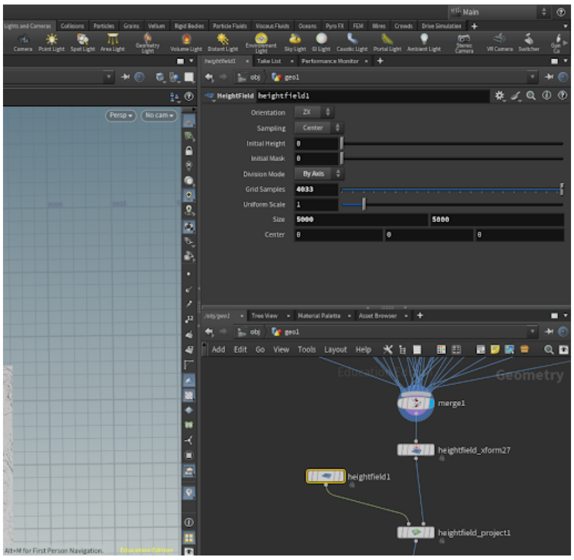


Figure 4.4: Connectio of nodes and settings for the new, merged Heightfield.

In the *Heightfield Project* node, the *Max Ray Dist* was set to 1500. This is the farthest point away from the projection points the software will detect. The highest point of our landscape is above around 1200 meters high. A number under that will lead to missed geometry, hence a number above is used.

Using the node *Heightfield Remap*, the projected landscape can be turned into a PNG image file. Pressing *Compute Range* will give the lowest and highest point of the landscape. For *Output Min*, the value 0 was used. For *Output Max*, the value 1 was used. This will remap the highest, lowest and in between values linearly to a value between 0 and 1. 0 correlates to black, 1 to white and numbers in between a shade of grey.

Lastly, a *Heightfield Output* node was used. An output directory was chosen. A filename was added ending with .png. This will output a PNG-image. *Output Type* was packed raster, format was *single channel* and type *16b fixed*. In the *Output layers*, *height* was chosen.

Pressing Save to Disk on the top of the Heightfield Output node saves a merged PNG image, which could now be used to create a landscape in Unreal Engine.

4.4.4 Result of Height Data Exploration

The first exploration phase of this project aimed to benchmark what could be possible regarding creating a digital twin of a forest. By using real world height data, landscapes were created reassembling the physical world in shape and scale. The results were promising as it was possible to use these landscapes inside of Unreal Engine. The results of the landscapes depended on the resolution of image used to generate it. A resolution from 2017x2017 to 4033x4033 pixels where tried. The higher resolution picture holds more detail to the landscape, while the lower could be used for cases where better performance was needed. The results are seen in figure 4.5.

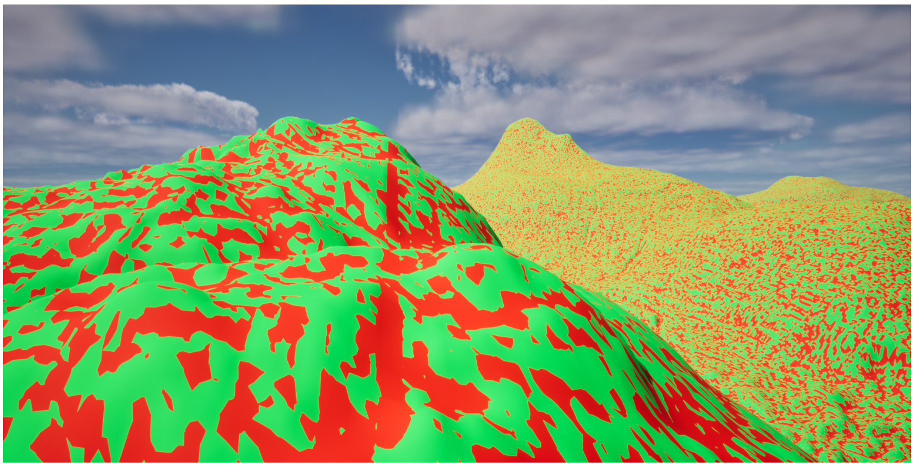


Figure 4.5: Red represent resolution of 2017 pixels while green represents 4033.

4.5 Creating vegetation textures using OCAD

OCAD is a mapping software used to create orienteering maps. Taking use of the already created maps, image textures can be exported from OCAD for generation of vegetation and other symbols which a map covers, inside of Unreal engine. OCAD has a free alternative called OCAD Viewer, which this project have utilized.

4.5.1 Exporting images from OCAD

An orienteering map of Idre Fjäll was received from the IOF, the stakeholder company in this project. Opening this OCAD-file, it previews an orienteering map of the area. To be able to export and use different images from OCAD, the symbols was first selected in Symbol Box. There are a lot of different symbols here, and some of them cover similar objects.

4.5.2 Full Map

The full map was exported for use in Unreal Engine. To do this, File->export was selected in OCAD. PNG file was used as export, with a resolution of 200 DPI. Selecting *Part of map* and then *Entire map* will give an export of the full map. This export was named *FullMap*.

4.5.3 Forest

The symbol for forest is white on an orienteering map. The symbol for forest, 405.000, was selected in the symbol box. The symbol was then right-clicked. Select->Invert was pressed to invert the selection. With every other symbol selected except the forest, F4 was pressed. This hides the selected symbols, and the symbol for forest was only visible.

File->export gives the export options for OCAD. PNG file was selected here, with a resolution of 200 DPI. Selecting Part of map and then Entire map will give an export of the full map.

This process was then repeated for every map symbol which can be generated. This means a different map export for the following symbols. These are referred to with the symbol names from the International Specification for Orienteering Maps, ISOM [34]:

- Dense forest (Different shades of green on the map including symbol 406.000, 408.000).
- Marshes (Striped blue symbols including symbol 308.000, 308.001, 309.000, 310.000, 310.001).
- Stones (Black circles including symbol 204.000. 204.001, 205.000).
- Stone Clusters (black triangles including symbol 207.000).
- Stony ground (smaller black dots including symbol 210.000, 211.000, 212.000).
- Open areas (Different yellow shades including symbols 401.000, 402.000, 403.000, 404.000).
- Open areas with trees (402.000, 404.000).
- Cliffs (201.001, 201.004, 201.005, 202.000)

Before being imported into Unreal, the images were taken into Photoshop for some processing. These images could then be used in Unreal Engine to generate 3D objects where they are placed on the map.

4.5.4 Preparation in Photoshop

To prepare the exported images, they were processed in Photoshop. There are a couple of steps necessary for them to be used as textures in UE.

The alpha channel would be used in UE to detect where to generate 3D objects. This is the transparency or opacity channel of the picture. Where objects should be generated, no transparency was wanted. Where objects should not be generated, full transparency is wanted.

Hence, everything outside of the symbols on the exported images from OCAD was removed.

To do this, every image was opened in Photoshop. Using *Markera->Färgområde* and then clicking the white area with the eyedropper, the white background was selected behind the symbols. Right clicking and choosing *Klipp ut till lager* would make this a new layer, which could be deleted. The background was now transparent. Going to *export->export as* gave the option to export as PNG. The background was kept transparent. The size was chosen to 1024x1024 to be optimized for UE. Using bigger images will be more costly to the performance in UE. For stones and cliffs, resolution was set to 4096x4096 instead. This was due to accuracy of the small objects. With low resolution the placement would be affected later in Unreal Engine.

The images was named as follows, in the same order as presented in 4.5.3:

- White1024
- Green1024
- Marshes1024
- Stones4096
- StoneClusters4096
- StonesGround1024
- Yellow1024
- YellowTrees1024
- Cliffs4096

4.6 Creating a virtual forest in Unreal Engine

With all files prepared using different software, the end one could be entered. Inside Unreal Engine the virtual landscape and forest could be created, to form a digital twin of the real area.

4.6.1 Landscape Creation

With prepared PNG images for both landscape height and 3D object generation, these could be imported into UE. This thesis has used Unreal Engine version 5.3.2 for the development.

With a new project open, Ctrl + B can be pressed to open up the content browser. Here the created height maps from before could be imported. By opening them in the file explorer, they can be dragged and dropped into the content browser. The files will be imported into UE.

Landscape creation is done in the *Landscape Mode* tab. This is found by pressing *Shift + 2*. By choosing new file, a new landscape will be created. The PNG made in Houdini was imported here. Some of the settings will be set automatically by UE, while others need to be changed:

- The heightmap resolution was set to the one exported from Houdini.
- A landscape material was applied here, but can be added later.
- The scale has to be calculated, to match the real-life size.

To calculate the right scale, UE has a technical guide for landscapes [33]. These steps were used to calculate the right scales:

Divide the wished size of the axis of your landscape by the resolution of the exported height map. Multiply by a 100 since UE uses cm as a unit. In this case: (5000 m / 4033 pixels)*100 This gave the scale of 123,977 for the X and Y axis of the landscape.

To calculate the height, another formula had to be used. Unreal calculates map height by values between -256 and 255.992 (this is stored with a 16 bit precision, which is the same precision we exported with from Houdini). This means that a Z-scale of 100 will give height values between -256m to 256m. The following formula gives the Z scale of the landscape:

$$Scale = (HighestPoint - LowestPoint) * 100/512$$

To calculate the Z scale of the landscape, the highest and lowest point were needed. These numbers could be accessed through Houdini, in the *Heightfield Remap* node as shown in figure 4.6. The Output Max and Output Min is our highest and lowest point. The difference between these two were multiplied by 100, going from meters to centimeters which is the UE unit. This number was then multiplied by 1/512, the ratio of how UE for height. The result was 134,708 for Z scale.

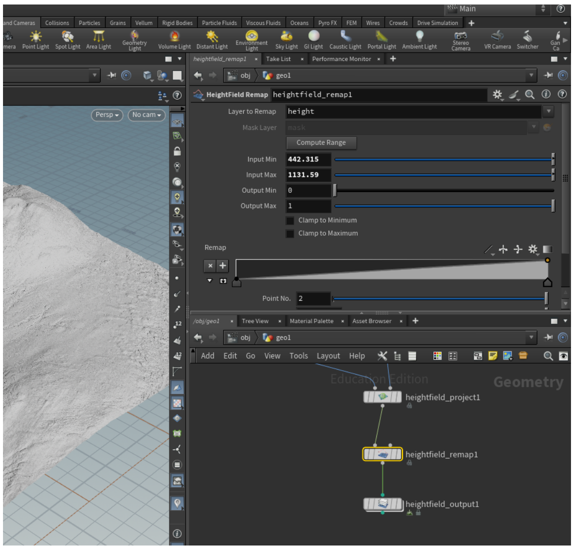


Figure 4.6: Output Max and Min values from Houdini.

The landscape was now correctly scaled to the real-life dimensions. Pressing Import will create the landscape.

4.7 Forest Generation

The 3D game software Unreal Engine has been used for this thesis. The real-time software produces frames faster compared to other 3D software using different short-cuts of lightning, shadows and geometry. For this project, both free assets and paid ones have been used.

The forest has been both generated procedurally and created manually. The focus has been to develop ways to procedurally generate as much as possible. This is a non-destructive way of working, allowing for reuse for other types of world-building. Through real-life landscapes, landscape materials, Procedural Content Generation and more the forest has been created using inputs from the real world.

4.7.1 Procedural Content Generation

Procedural Content Generation, or PCG, is a tool for creating content or tools inside of UE. It allows for building repetitive content like cities or biomes using different input and 3D objects [35]. PCG has been used for this project to replicate the forests of Idre Fjäll to the best extent possible. Taking use of the texture images from OCAD, different vegetation can be generated onto the landscape. This allows for creating a replica of the real-world with vegetation well matched to the ground.

PCG can generate points in space. These can be placed onto the landscape. These points can be replaced with static meshes containing trees, grass and other 3D objects within a forest. By taking use of noise and density, the generation can be randomized to replicate nature.

4.7.1.1 Importing OCAD Textures

The first step of the world generation is importing the image textures from OCAD. By pressing Ctrl + B in UE, the content browser is opened. The import was done by dragging and dropping the images into the content browser. Before being used in the PCG, they had to be slightly altered. By double-clicking an image, it was opened in a new window in UE. Here, settings were changed for every texture:

Texture Group -> UI Compression Settings -> 3DVectorDisplacement

By changing these, error messages will be avoided later in the PCG creation. The textures can not be used to generate points for the PCG, if these are not changed.

4.7.1.2 Vegetation Generation

To generate the forest, the vegetation was first implemented. To create a PCG node, Ctrl + B can be pressed to open up the content browser in UE. By right clicking here, and writing Procedural Content Generation a node of this kind was created. By double-clicking it, the node graph where coding can be done will be opened.

Similar types of node networks were used for all generation, with slight changes for different objects.

4.7.1.3 Normal Forest

The symbol for forest on an orienteering map is white. This is defined as normal forest with normal runnability. The following was done to create the white forest:

- A *Get Texture* node was created by right clicking in the node graph and searching for texture.
- The image *White1024* was used as Texture input.
- Input channel was changed to Alpha.
- Texel size was set to 800.

The texture input takes use of the OCAD texture for white forest. By changing the channel to Alpha, the PCG will generate points in 3D space where the value for the Alpha is value 1 (which is equal to white) while no points will generate on a value 0 (which is equal to black). Grey values in between will generate points as well. These can be used for generation, or filtered away in the PCG graph to get less trees on some parts or edges.

The created points could now be randomized:

- A *Randomize points* node was created and connected to the texture node.
- The offset was set as: X - 500, Y - 500, Z - 5
- The rotation was set as: Z: 360

This will create randomization of the nodes in 3D space. They will randomly be placed with an offset of up to +-500 units in X and Y direction. The rotation on the Z axis will be randomized between 0 and 360 degrees.

Next, the points in space were projected onto the landscape::

- A projection node was created.
- The *Landscape Height* was plugged into the *Projection input*.

This would put the points onto the Z height of the landscape in the scene, placing each point on the ground instead of on the same level.

The points could now be used to spawn other 3D objects:

- A *Static Mesh Spawner* was created.
- By pressing *+ Mesh Component*, different static meshes could be replaced for the points.
- One Mesh component was created for each static mesh, which is for each different type of tree.
- For each Mesh Component, the culling was set to 40 000.

By replacing the points with static meshes (3D objects), the forest could be generated. The culling was set to 40 000, which means that the objects will disappear in the camera when 40 000 units away. This increases performance in the scene, where not all trees are loaded in at once.

4.7.1.4 Dense Forest

Forest of denser character was generated separately, but using the same logic.

- A *Get texture* node was created.
- The *Green1024* image was used as the input texture.
- The texel size was set to 500.
- A *Transform Points* node was created.
- Transforms were set as offset X/Y: +-500 and rotation Z: 360.
- A projection node was created, where the Landscape height was connected.
- A *Static Mesh Spawner* was created where meshes where input in the Mesh Component.
- The start/end culling was set to 40 000 for each Mesh Component.

4.7.1.5 Marshes

For wet areas, or marshes, the procedure for dense forest could be repeated. The difference in settings were:

- Marshes1024 as input texture.
- Texel size was set to 200.
- Transforms were set to -200 and 200
- Mesh components were switched from trees to marsh growth.
- The start/end culling was set to 20000 for each mesh component.

4.7.1.6 Stones

The same logic as used before could be applied for stones. The difference in settings follows:

- Stones4096 was used as the texture input. The image texture for stones had to be a higher resolution due to the small symbol.
- Texel size was set to 500.
- Offsets were set to 0 and 0.
- Mesh components were switched to different stone meshes.
- The start/end culling was set to 20000 for each mesh component.

4.7.1.7 Stones Ground

Same logic could be applied for smaller stony areas on the ground:

- StonesGround1024 was used as texture input.
- Texel size was set to 500.
- Offsets were set to -300 and 300.
- Mesh components were switched to smaller stone meshes.
- The start/end culling was set to 20000 for each mesh component.

4.7.1.8 Stone Clusters

Same logic could be applied for stone clusters:

- StoneClusters1024 was used as texture input.
- Texel size was set to 500.
- Offsets were set to -300 and 300.
- Mesh components were switched to small stone clusters as meshes.
- The start/end culling was set to 20000 for each mesh component.

4.7.1.9 Open Areas Undergrowth

Same logic could be applied for open areas:

- Yellow1024 was used as texture input.
- Texel size was set to 500.
- Offsets were set to -500 and 500.
- Mesh components were switched to vegetation seen in open areas as grass and smaller bushes.
- The start/end culling was set to 20000 for each mesh component.

4.7.1.10 Open Areas Trees

Same logic could be applied for open areas with trees:

- YellowTrees1024 was used as texture input.
- Texel size was set to 500.
- Offsets were set to -500 and 500.
- Mesh components were switched to smaller trees seen in open areas.
- The start/end culling was set to 20000 for each mesh component.

4.7.2 Problem Areas for PCG

There are some areas where PCG is hard to implement. Objects that require a specific individual rotation or scale can be difficult to generate, since each individual point cant be randomized, but need specific inputs.

4.7.2.1 Cliffs

For generation of cliffs the points need not just to be placed at the right spot, but rotated the right way compared to the landscape. For all the other points generated so far, the rotation has not been important. The rotation being important, is a more difficult implementation with PCG.

To fix this, some modification to the PCG had to be done. In figure 4.7, the first iteration of the node tree for the cliff generation is displayed.

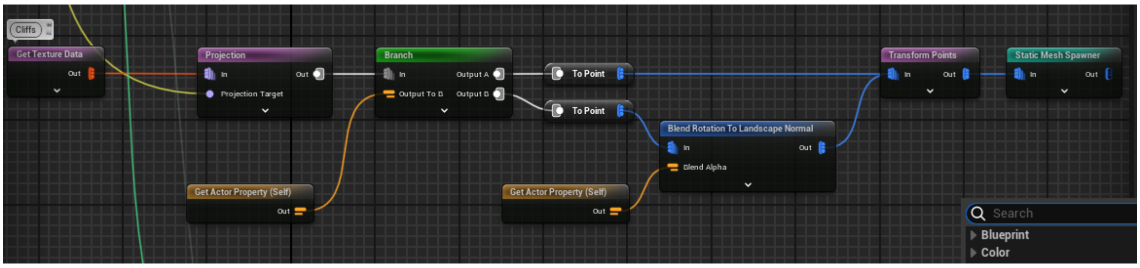


Figure 4.7: Node tree spawning cliffs following the landscape normal, on the right locations.

To create this node steup, the following was done:

- A *Get Texture* node was created. Cliffs1024 was used as texture input.
- *Texel size* was set to 1100.
- *Projection* was set to project positions only.
- To be able to turn choose if the landscape normal affects the cliff rotation, a *Branch* node was created.
- A *Get actor property* was created and set as *self*. This allows for the input to be used outside of the PCG graph (inside of a blueprint for example).
- Inside of the *Get actor property*, the *Property Name* was set to *EnableLandscapeNormalBlend*.
- A *Static Mesh Spawner* was used, to input meshes in the *MeshComponent*.
- The *start/end culling* was set to 20000 for each *mesh component*.

Next step was setting up a Blueprint Actor were the PCG could be controlled. By doubleclicking the Blueprint it can be edited. The following was done in the Blueprint:

- In the top left *components* of the Blueprint, a PCG was added by pressing Add. See figure 4.8.
- Selecting the PCG, the PCG graph of interest could be added under *Details->Instance*. See figure 4.8.
- A Box Collision was also added, due to a bug that could occur without it.
- Next, a variable was created of the type Boolean. It was named as the Actor Property from the PCG: *EnableLandscapeNormalBlend*. By pressing the eye symbol next to it, it is made public and editable.
- Another Variable was created called *EnableLandscapeNormalBlendAlpha*. It was set as a float. This variable will be used to control the mix between the original rotation of the cliff and the landscape normal.

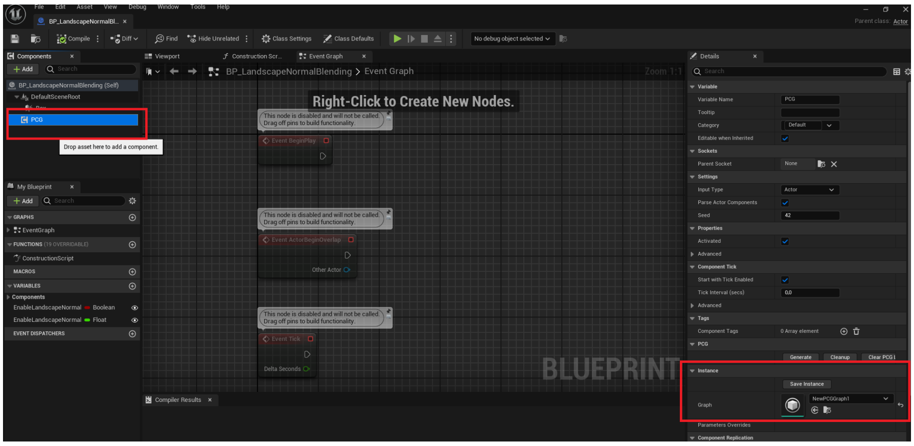


Figure 4.8: Node tree spawning cliffs following the landscape normal, on the right locations.

Going back into the PCG Graph, a custom node handling the calculation of the landscape normal at every point was created: An Apply scale to bounds node was created. By copying the node in the Content Browser, and pasting it into the same folder as the PCG Graph is stored the node could be edited:

- Rename the node to *BPE LandscapeNormalBlend*.
- By double clicking the node in the Content Browser, the node was opened. See figure 4.9.
- Under *NodeTitleOverride*, the node name could be changed.
- The name was set as *Blend Rotation To Landscape Normal*.

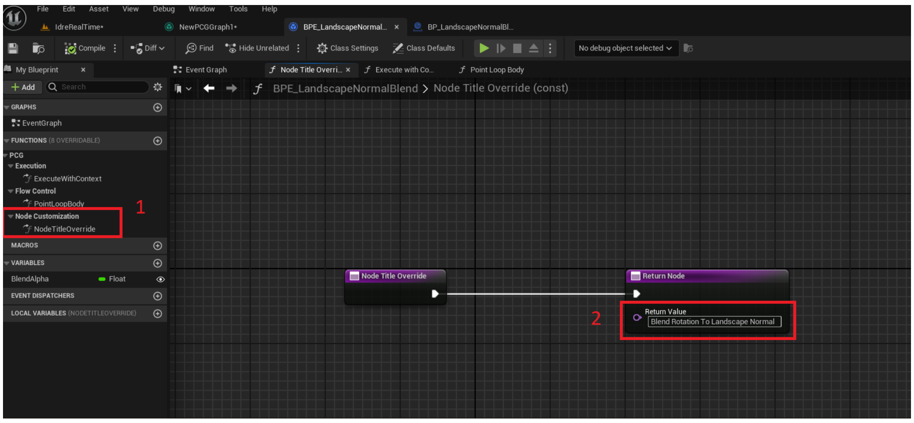


Figure 4.9: Custom node called BPE LandscapeNormalBlend. The numbers show where to click to rename variables inside of it.

By clicking *PointLoopBody*, as seen in figure 4.10, the window where the different landscape normals were calculated. This part will loop through all points of interest and calculate surface normals to the landscape closest to the point. The full node graph is seen in the same figure. The following was changed in here:

- A *Line Trace By Channel* node was created and connected to the *Point Loop Body*. The Line trace does a collision check along a given line. The return is the first hit it receives.
- From the *Break Transform Location*, an Add and Subtract node was created. Each was input with 3000 for the Z value. The Add was connected to Start of Line Trace, and Subtract was connected to End.
- From the *Out Hit* of the Line trace, a *Break Hit Result* node was created. This node extracts the results of the trace.
- A *Lerp (Rotator)* node was created and connected to *Impact Normal* from Hit Result. This linearly interpolates between two inputs, or uses either if alpha is 0 or 1.
- From the Alpha, a variable was created by dragging out from the node and selecting promote to variable. It was named *Blend Alpha*, to be able to blend between the rotation from the Line Trace Hit and the original rotation of the point.
- A *Select Rotator* node was created and connected to the Lerp as A value. The B value uses the original rotation from the Break Transform node.
- To the Pick A socket, the Return value from the Line Trace is connected. This return is a Boolean, true or false. If true, the *Select rotator* chooses value A as return. If not true, value B is chosen.
- A *Make Transform* node was created. This is to put together the transforms again, after breaking them before.
- The *Select Rotator* was connected to the Rotation. Location and Scale uses the original values from the Break Transform node.
- The *Make Transform* nodes return value was connected to transform in the *Set members in PCGPoint* node.

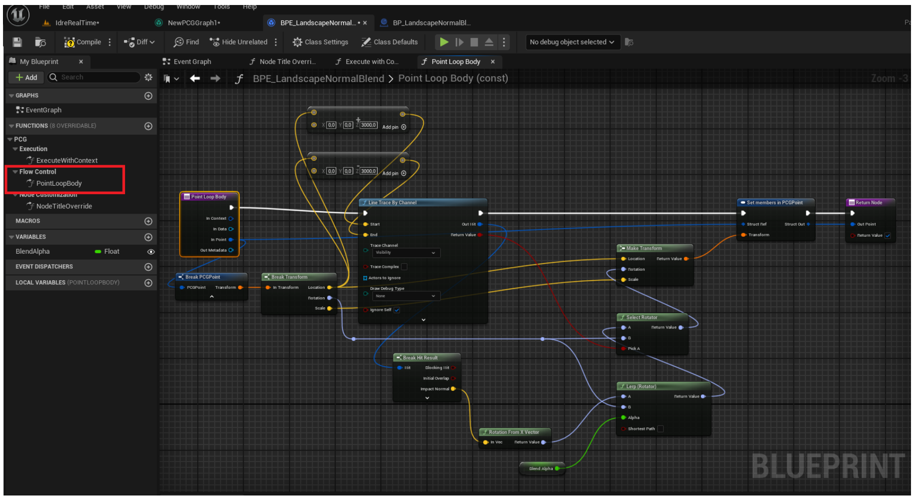


Figure 4.10: The code changed inside of the Point Loop Body.

By going back to the PCG Graph, this custom Blueprint Element we created can be used in the PCG Graph:

- By right clicking and searching for *BPE LandscapeNormalBlend* the node could be found.
- It was connected to the Output of the Branch Node, as seen in Figure 4.7.
- Another *Get Actor Property* was created and connected to Blend Alpha. This lets us control the Blend Alpha. Property Name for the Get actor was set as *EnableLandscapeNormalBlendAlpha*.
- This node was connected to a *Static Mesh Spawner* where meshes for cliffs were inserted into mesh components.
- Output A from the Branch was also connected to the static mesh spawner.

4.7.3 Placement of the PCG

For the PCG graph to match the real-life vegetation, it had to be placed with the right scale and position. This was done through matching it with an orienteering map.

The landscape was duplicated, to have a copy where the orienteering map could be projected. A material was created with the node network as figure 4.11. The material was created through these steps:

- A *Texture Sample* node was created. The FullMap image was used as texture input.
- A *ScaleUVsByCenter* node was connected to the UVs. This allows for scale the UVs of the texture to fit the landscape.
- A *CustomRotator* node was connected to the UVs of the node before. This allowed for rotation of the texture. No rotation was ended up being used.
- A *TexCoord* node was created. This was connected to an *Add* node which was connected to the UVs of the *CustomRotator*. Here the UVs could be scaled to fit the landscape. Through trial and error, the right input ended up as: *UTiling: 0,000349* and *VTiling: 0,00031*.
- A *VectorParameter* node was created. This was connected to a *Mask (R G)* node which was connected to the B value of the Add node. The parameters Red and Green value allows for moving the texture on the Landscape. Through trial and error, the used values were: R: 0,0875 and G: -0,045.

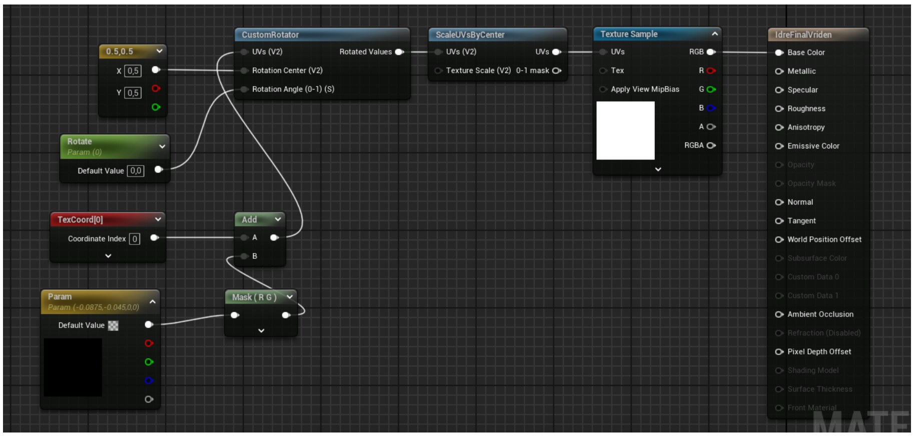


Figure 4.11: Node tree for the map material.

The map projected onto the landscape could not only be used to place the PCG. As a re-design of the normal 2D orienteering map, the 3D map could be used to create a more understandable way of presenting a course.

4.8 First Prototype - 3D Twin

The first design prototype was a brainchild of early brainstorming, exploration and design process. The prototype is presented as the one used during the evaluations. Screenshots from the video prototype will be shown. The full prototype can be seen in Appendix B.

For the first prototype, a full digital twin of the Idre forest was built. However, for user tests to be conducted some use cases needed to be tested. Here, the needs of the International Orienteering Federation became important. Through discussion, they expressed how they would like to use the twin in their broadcasts. These could then be tested to as if they improved understandability for the viewers. Through discussion with input from the project team and the company, a video prototype was created from the digital twin of the forest. The use cases tested in the video prototype was decided as the following:

4.8.1 3d Twin - Forest Overview

The first prototype presented to the viewers was a forest overview. This showed the forest that an orienteering competition could be held in. Further it presented landmarks, as where the arena and start of the competition were located. Figure 4.12 shows 2 screenshots from the flyover.

(a) Overview of the forest. (b) Competition arena located in the terrain.

Figure 4.12: Digital forest overview.

4.8.2 3D Twin - Forest Ground View

The last part of the prototype showed a view from the digital forest. This part, seen in figure 4.13 could be used to show route-choices, mistakes or other happenings from inside the forest.

Figure 4.13: View from inside the virtual forest.

4.9 Orienteering Map in Three Dimensions

The ordinary orienteering map can be hard to understand. A 2D map with symbols that gives few cues to what they stand for can be impossible to decipher for the untrained eye. To create something more visually telling, a 3D version of it was developed.

This was based on the theory of visual semiotics. A image providing depth cues can provide the interpreter with a sense of 3D, from a flat 2D image. For a 3D map, this would include occlusion of some parts of the terrain, texture detail on the different terrain parts and light and shadow to explain the ups and downs of the ground, as explained by Wideström [13].

He further talks about signs of signs, specifically indices. These refer to to factual connections from the world, where the viewer needs experience of the connections from the real world. These signs are the closest to orienteering symbols, where their factual connection is through provided through regulations set by the International Orienteering Federation. Each object in the forest, wether a tree or a stone, has its own symbol that has to be learned to be understood fully. The experience needed to understand an orienteering map can be extensive, but perhaps the 3D map can provide more cues to what it is trying to describe. This was later tested in the evaluation, where interviewees got to see a normal 2D orienteering map and the 3D map prototype.

4.9.1 3D Map

The 3D landscape created from real-life height data could not only be used for the 3D Twin, but for the 3D Map. By projecting a normal 2D orienteering map on top of the, height differences could be explained to the viewer through visuals cues. By doing this, hills and depressions could be seen by viewers on the map. With or without map experience, the landscape could be understood by the viewers. Hopefully, the understandability of the broadcasts could be improved by using these visuals cues.

4.10 Semi-Structured Interviews

To conduct user research on the developed design prototype, a semi-structured interview was created. This method is useful for extracting rich data from the test subjects. This data in turn, is valuable to understand the actual feeling and experience of the viewer. Since a TV broadcast isn't about the usage of a product, but more a viewing experience, this type of data was focused on. Other methods of evalution, for example user error tests, would be less resourceful here. How many clicks it takes a person to perform a task is not possible for this project. It was more important to evaluate the understandability of the prototype and what it makes the viewer feel when seeing it. The semi-structured form was chosen to have room for further probing during the interviews. This allowed for new questions to arise and different areas of interest to be explored during the interviews.

A total of five people were interviewed. All these correlated to different ser groups. They further represented different ages and genders. The interviewees spanned between 23 to 80 years old, where 2 were female and 3 male.

4.10.1 User Groups

Orienteering broadcasts can have up to hundreds of thousands people watching a broadcast. With viewers of all ages and experience of orienteering, it was important to do user tests of people from all possible groups. These are further called viewers groups.

4.10.1.1 Novice Viewers

Novice viewers without any experience of orienteering would be of importance for data collection. Since the understandability of the broadcasts are trying to be improved, these viewers are of big interest. If and how the visuals they are presented can be understood needed to be tested. Further, their input of improvements for be very useful for further design work.

4.10.1.2 Intermediate Viewers

The intermediate users have some experience of orienteering or its TV broadcasts. However, they are not the most experienced with orienteering maps. The understanding of these viewer are of interest since they are open to learn more about the sport and need the tools provided for further understanding.

4.10.1.3 Expert Viewers

Expert Viewers have a great understanding for the sport of orienteering. They practice it regularly of have before in their life. They understand all the symbols of an orienteering map with ease. Further, they have great experience of orienteering broadcasts, what they show and might have own ideas to how they can be improved.

4.10.2 Evaluation questions

To construct the interview in a semi-structured way, questions were created to evaluate the prototype properly. By starting off with warm-up questions, the interviewee gets a good introduction to the area researched. They were shortly asked about the sport of orienteering and if they have any experience with it. This introduces the area with questions that are easy to answer to. The hope is to make the interviewee relaxed to receive honest responses later.

After a short introduction of what the Chalmers Thesis project is researching, the following questions were asked:

- What experiences do you have when it comes to the sport of orienteering?
- Have you ever watched orienteering on TV before?
- If yes: What was your experience of the broadcast?
- If no: How so?

With these questions, the area of interest is introduced. Further, the level of expertise can be determined of the subject. What experience do they have of orienteering, and have they seen it on TV before? What did they think of the earlier broadcasts they have seen, or is there any reason to why they haven't watched it?

After this warm-up phase, the real research area was ready to be explored. The ultimate design problem for this project is to research wether 3D visualization can improve the understandability of orienteering on TV. To test this, the visual semiotics of the prototype was interesting to analyze. The orienteering map was the most interesting, due to the symbols of a map. Does the viewer understand the signs that an orienteering map consist of? What is the map trying to describe, and why is it shown?

With questions covering the understandability of the images shown, the visual semiotics could be tested at the same time. Three basic areas of interest were constructed to uncover what the subjects interpreted the pictures as:

- What do you see?
- What is it trying to describe?
- Why is it being shown to you?

Here 3 level of understandability can be tested. The first just ask the viewer to tell what they see. The second one ask them to define what the picture is trying to describe. The third asks them to go into why it is being shown to them. These three areas could be branched out depending on what part of the prototype was shown to the interviewee.

The prototype had 3 different parts that could be tested. The first was a realistic fly-over describing the competition forest and arena. The second was a 3D map shown in different angles to the viewer. The third was a transition from 3D map to forest, showing a possible route the runners could take. The branched out questions for each part can be seen in Appendix A.

The last part of the interview covered another topic for evaluation: excitement. The broadcasts should aim to be understandable for viewers. But, they also need to be enjoyable. By asking questions around which parts of the prototype they liked the most, this area could be looked into as well.

4.11 Thematic Analysis of Evaluation Data

A thematic analysis was performed on the qualitative data set collected from the interviews. This to be able to identify common themes within the interviewees answers. Doing this could lead to further understanding of their thoughts and feelings behind their answers. The steps one, three and five seen in figure 3.3 were used to perform the procedure. The other steps were skipped due to time limitations.

4.11.1 Familiarization of Data

Since the data collection was done by the project theme of one person, the data was from the beginning somewhat familiar. By further reading the notes through after the end of interviews, more ideas of the answers could be gathered. When interviews where complete, the data could be searched for common themes.

4.11.2 Searching for Themes

For effectivity and time reasons, the next step consisted of identifying themes within the data. By collecting similar statements into categories, some common thoughts and opinions of the interviewees could be gathered. The common themes can be seen in Appendix C.

4.11.3 Defining and Naming Themes

By sectioning similar statements together, themes could be identified. When the full data set had been analyzed, themes were established within the data. These were used in the Re-design of the prototype for improvement.

From the user input, positive feedback was gathered around the understandability of the 3D map. Users without experience of orienteering maps could understand height differences without help. Further, the digital forest was an exciting addition to real camera footage. However, many subjects expressed concerns about the digital forest. Firstly, they did not want it to replace real camera footage. They could see it as a good complement to where cameras were not placed. Secondly, the realness of the forest were questioned. This was a theme identified in the analysis (as seen in the result chapter]. The underlying feeling identified here was that the experienced viewers thought that viewers wouldn't get a true feeling of what the runners experienced in the forest. The digital forest didn't look close enough to the real one, and hence could provide a false picture of the real world.

The re-design of the prototype was hence focused on making a better replica of the Idre forest, through differerent technical improvements.

4.12 Design Iteration

After user testing and data analysis, the design could be iterated and improved. The 3D forest was improved in a couple of different ways to enhance the realistic look and solve issues that weren't possible before. Further, the themes identified from the user testing was taken in account for the redesign. Creating a forest that further reassembled the look of the real one was focused on.

4.12.1 Landscape Material

To improve the ground floor of the forest, a landscape material was used. The Landscape Material is a paid asset from the Fab marketplace in Unreal. This can generate different types of textures and foliage onto the ground. By painting onto the landscape, ground objects like paths or open areas could be created. The landscape material puts a texture on the ground, as well as procedural foliage.

To apply the new landscape material, the landscape was selected. Under Details -> Landscape Material a new material can be dragged and dropped. To start painting Landscape Layers, Landscape Mode was entered. To paint the Landscape Layers, some steps had to be taken to prepare:

- Inside of *Landscape Mode*, the Paint option was selected. Here the Landscape Layers of the landscape can be seen.
- For each layer, a *LayerInfo* was created by adding it under the layer. They were saved in the same folder as the Landscape Material. These store the information of each painted layer.
- The landscape layers could now be painted onto the ground, using the brush in paint mode.

4.12.1.1 Forest Ground

For the ground in the areas with forests, 2 different Landscape layers were used: Moss and Mulch. By using the brush, the 2 different layers were painted randomly onto the ground of the landscape where trees were generated from the PCG.

The Moss and Mulch layers generate foliage like grass, mushrooms and sticks on top of a texture. These were altered to fit the forest of Idre fjäll. Images from the forest of Idre were used as reference. The forest area of Idre is mostly covered with moss and blueberry as can be seen in figure 4.14, from the Idre World Cup 2021.

Figure 4.14: Reference picture of the forest from Idre.

To make changes in the foliage spawned on the ground, the Nordic Conifer Biome was found in the content browser. Going to the Material Library -> GrassLayers, the LG Moss was double clicked to open for edit.

Here, meshes of blueberry bushes were added under Grass Mesh. The settings changed here was the following:

- Density was chosen to 400, to spawn a dense blueberry field on the ground.
- The scale was set to 0.9 to 1.3.
- Culling was set to 10 000 for performance reasons. When the camera is 10 000 units away, the foliage fades out.

- *Cache Invalidation Behavior* to Static. This stops the shadow from updating every frame, since the bushes have movement in them.

4.12.2 Paths

Paths could be spawned using PCG, spawning 3D objects that can be seen on a path. A more performance saving way of doing it however, was taking use of the landscape material. By using another material than the forest ground, paths could be painted where needed. Through splines put on the landscape, the areas for paths could be defined. Assigning a path material to these splines defines where the material should be painted, instead of doing it manually. This in turn, made changes possible as the splines are editable.

Splines for paths were created in Landscape Mode (Shift + 2). By right clicking on Edit layers, a new layer could be created. This was named Splines. By right clicking on that layer and choosing Reserve for Splines, the layer would consist of splines only. To create splines inside of the layer, the following was done:

- Splines were selected in the Manage Tab of the Landscape Mode.
- By holding down Ctrl and Left clicking on the landscape, control points for a spline is created.
- If one control point is selected, and Ctrl + Left click is repeated on the landscape, another control point will be created. The line in between the control points are called segments.
- In the left menu, *Select All: -> Control Points* was selected. This selects all control points in the layer.
- Under details for the control points, the right side menu, the *Half-width* of the points were set to 100 and the *Side Falloff* to 150. The paths will be 100 cm wide with a fall-off on the side 150 cm.
- In the left menu, *Select All: -> Segments* was selected. This selects all segments in the layer.
- In the right menu, under *Details -> Layer Name* a layer can be added. *Path* was entered here, being the layer name in the Landscape material. This will assign the Landscape Layer Path onto all splines, creating paths on the ground.

4.12.3 PCG

For the PCG Graph, some changes were made to improve the visual quality of the digital forest. A bigger variety of meshes with higher fidelity were used.

4.12.3.1 Trees

The trees were changed with meshes from the Nordic Conifer Biome pack. This was done by opening the PCG Graph. The Static Mesh Spawner was selected. In the Mesh Component, the trees were changed for the Nordic Conifer trees. Adding more

Mesh Components allowed for using more tree meshes, getting a bigger variety of trees in the forest. This allowed for a more natural design, since every tree in a real forest looks different, making it less repetitive.

4.12.3.2 Cliffs

The cliff generation was a problem area for the first design iteration. Another way of spawning cliffs were used for the re-design, with more customization opportunities. The cliffs were spawned through a texture map, like the rest of the 3D objects, for correct placement on the landscape. By spawning actual meshes onto the landscape, and not mesh instances, the cliffs can be rotated and moved individually. This allowed for manual customization of the cliffs to fit the landscape. They can be rotated to fit the landscape, and slightly moved if needed. The following steps were taken in the PCG Graph, which can be seen in figure 4.15:

- A *Get Texture* node was created, were Cliffs4096 were used as texture.
- *Texel size* was set to 500.
- The *Projection* node was connected to *Get Landscape Height* trough the Projection Target.
- *Transform points* were set to scale the meshes from 0.5 to 0.7.
- A *Spawn Actor* node was created. *Template Actor Class* was to *StaticMeshActor.*
- *Allow Template Actor Editing* was turned on, to be able to edit the individual meshes.
- *Template Component* was set as a rock ledge from Nordic Conifer Biome.

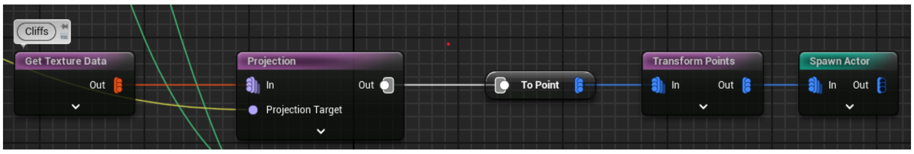


Figure 4.15: Node tree spawning transformable cliffs on the right locations.

4.13 Extracting Key Factors for Understandability

With the design process nearly finished and data analysis performed, an answer to the research question had started to form. Through the thematic analysis some themes emerged within the answers of the interviewees that could be used as a base. With the data gathered and evaluated, the findings could be used to form valuable ideas.

By taking use of the themes formed in the evaluation, these could be interpreted into concepts valuable for designing visuals for understandability. The 3D world could provide visual cues that was not possible using flat 3D maps and hence a key factor was derived from here.

Through the digital forest, viewers could make real world connections. They could receive information regarding what symbols correlated to, or experience them in a more understandable way. Viewers expressed they could actually understand if the landscape is steep or flat, and get a better feeling for what the runners experience in the forest.

Further, having a balance between the understandable and the exciting was important. While some viewers found the digital forest compelling, others could get better understanding from the 3D map. By using the right medium for the right task, and balancing the both, the right balance might be found.

4.14 Deep Learning Super Sampling 4.0

The project takes use of Deep Learning Super Sampling 4.0, which is a plug-in for Unreal Engine. DLSS 4.0 is a collection of different technologies to increase frame rate and performance inside UE and games made in UE. DLSS uses Multi Frame Generation to render up to 3 extra from, from each rendered frame using AI. Ray Reconstruction generate extra pixels in scenes that rely on ray-tracing, hence improving image quality. Further, DLSS Super Resolution renders a lower resolution image, to then use AI for upscaling to the desired output. Through this, the performance is boosted. Lastly, Deep Learning Anti Aliasing uses an AI-based anti-aliasing method to provide a better image quality for a lower performance cost. The described technologies requires a 50 series of Nvidia RTX Graphics card to run [36].

To install the DLSS 4.0 plugin, it was downloaded from the Nvidia DLSS website. The folder Plugins was unzipped and copied to the location seen in figure 4.16, in the File Explorer. With the UE project open, the plugin can be activated under Edit -> Plugins. By searching for DLSS, 4 alternatives shows up which were all activated.

To be active in the viewport, the working window of UE, it has to be activated inside of the project settings. In Edit -> Project Settings, the setting *Enable DLSS/DLAA to be turned on in Editor viewports* was set to true.

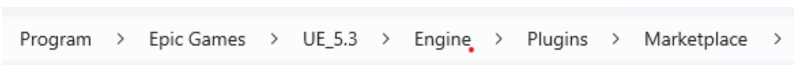


Figure 4.16: The folder where the DLSS code has to be copied into for installation.

5

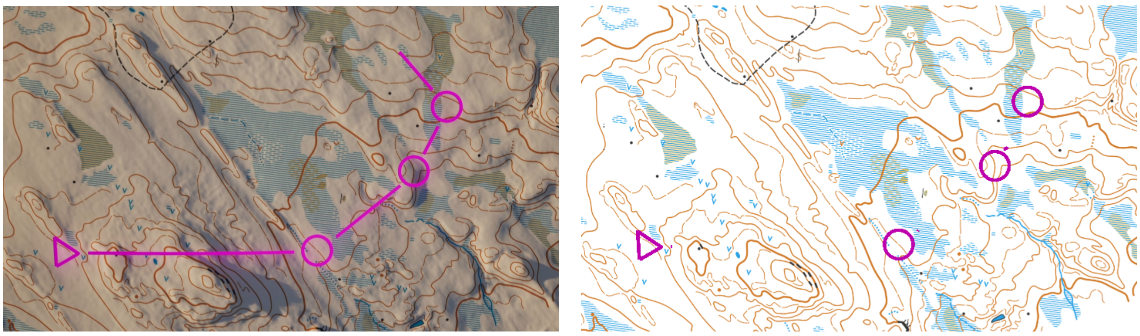
Results

The results of the design process are presented in this chapter. The final prototype re-designed is presented. Further, key factors for improving understandability within orienteering broadcasts are defined.

5.0.1 3D Orienteering Map

The first part of the prototype is a re-design of the normal 2D orienteering map. This design is a 3D version, using depth cues to describe its landscape. Since the map is created in a 3D software, any view can chosen to look at it from.

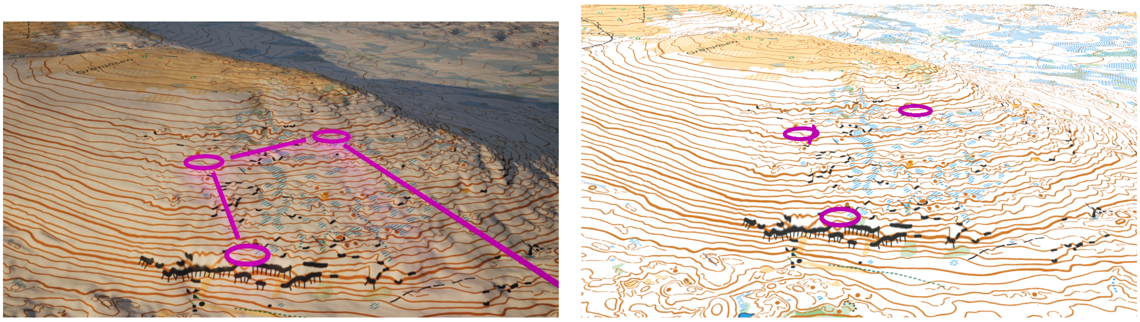
The first view presented of the prototype shown was from the top, looking straight down onto the landscape. A screenshot can be seen in figure 5.1a. The same figure shows a comparison to a view of a normal map, without terrain shadowing.



(a) 3D Map. (b) 2D Map.

Figure 5.1: 3D Map, with and without terrain shadowing.

The other angle shown to the audience is the one seen in figure 5.2a. This view presented the map and landscape from an angle, instead of from the top. A comparison to how a map would look without the terrain shadowing is presented in 5.2b.



(a) 3D Map. (b) 2D Map.

Figure 5.2: 3D Map, with and without terrain shadowing.

5.0.2 Routechoice 3D Map

The last part of the prototype showed routechoices of different runners on the 3D map. A screenshot example is shown in figure 5.3.

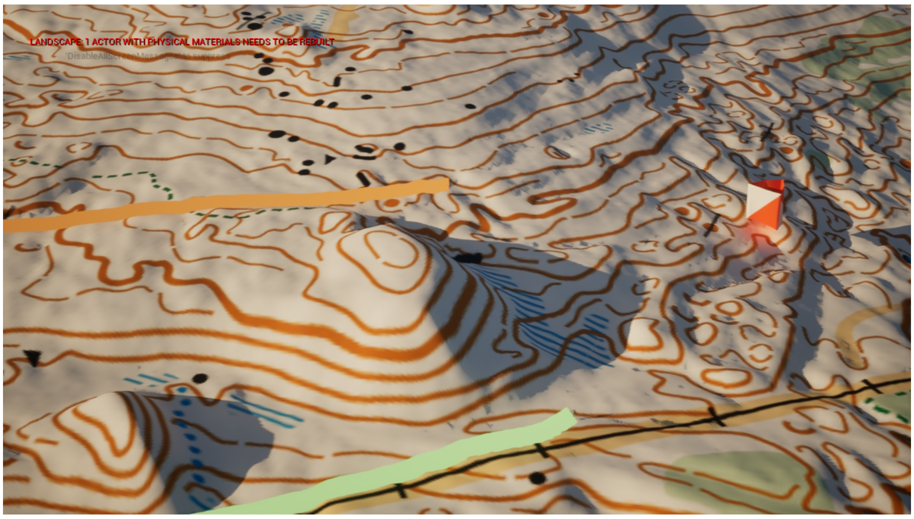


Figure 5.3: Routechoices shown on 3D Map.

5.1 Thematic Analysis of the Evaluation Data

The evaluation was carried out through semi-structured interviews. By analyzing the results using Thematic Analysis, themes could be identified among the interviewees. These are presented in 3 parts, starting with the data around the first part of the prototype.

5.1.1 Forest Overview

For the forest overview, the interviewees where asked questions to analyze their understanding of the videos they were shown.

From the thematic analysis, the identified theme here was that all the interviewees understood that this was a competition arena for orienteering. The forest describe where they are running and the text placed the arena and start in the forest.

Further, some of the viewers showed excitement over the flyover. They described it as realistic and cool.

The view had some possible room for improvements. Some text passed by too fast to be read the first time. More 3D objects on the arena and starting points was also asked for, since these usually have audience and other objects in the physical world.

5.1.2 3D Orienteering Map

For the 3D orienteering map, people from all expertise groups understood what symbols of the map tried to convey.

The top view gave viewers a good understanding of hills and depressions. When being compared to a normal 2D map, they would prefer this one as they can more easily understand the terrain. Even expert viewers, who already had a good understanding of the terrain enjoyed the 3D map.

However, this view was not understandable for a novice viewer. Without experience of the map, the only understood symbol was blue for water.

The 3D view that was shown in an angle for the viewers (figure 5.2a, did give an even better understanding for the map in some cases. All the interviewees understood that height here, where a big mountain was shown. Some liked this angle as it gives a change in the viewing experience. But, these should complement each other as the top view gave a better overview of the map.

None of the interviewees preferred the 2D map over the 3D map. Some did on the contrary enjoy the 3D map, expressing excitement over this visual way of seeing the orienteering map.

5.1.3 Forest Ground View

The transition from 3D map to forest was a appreciated one. The viewers thought it was an exciting feature. The bigger part understood that this view showed how the forest could look. Some realized it tried to show off a route-choice between two controls, while others didn't.

Some concerns about the virtual forest were raised. Some thought the forest did not look like Idre. With this in mind, they drew the conclusion viewers will think this it what the forest actually looks like. This was seen as a problem and it should not try to replace normal cameras from the forest. But, they could see it be used for parts where cameras are not placed. An example could be route-choices, where different runners choices are shown in the virtual forest.

5.1.4 Routechoice 3D Map

Some interviewees, depending on time, where shown another part of the 3D map with route-choices on.

The identified themes here were similar to the earlier answers, where it was clear to the viewers how the landscape was shaped. A novice viewer expressed that the longer route-choice probably was chosen due to it being a flatter route, whilst the short route was more hilly.

An expert viewer expressed that he could actually get a feeling for what the runners are experiencing in the forest.

An issue for the 3D map arose. In specific angles, symbols could come occluded by others shapes. Further, one person expressed they wanted to see the full route they were running instead of the camera zooming in at the start.

By sectioning similar statements together, themes could be identified. The common statements can be seen in Appendix. When the full data set had been analyzed, the following could be established:

5.2 Results of Thematic Analysis

For the results of the thematic analysis, the data showed:

- The majority understood what the forest overview represented.
- The majority could understand what the 3D map represented.
- The majority could understand what the forest view represented.

For the forest overview, all the test subjects understood what was shown. It was an overview of the forest that the orienteer would run in. The texts showed different important landmarks in the forest. They understood this was shown to give the viewer an idea of where positions were located compared to each other.

Most of the subjects would understand the 3D map and what is represented. Even novice viewers who didn't have experience with orienteering maps would understand height differences. They could point out hills and depressions in some cases, using the depth cues with shadows as help to identify these. All the subjects would prefer the 3D version over the flat 2D version, due to the better feeling of the landscape with the terrain shadowing.

When it came to other symbols, subjects with experience of orienteering maps could identify stones and marshes for example. But, viewers without orienteering experience had a hard time knowing what these symbols represented. Stones were not identified by any inexperienced subjects. The blue symbols, for marshes, were guessed to represent water by the novice viewers. Other symbols like cliffs were not identified correctly by the new viewers either.

When the full data set had been analyzed, the following themes had been identified:

- Improved understandability for height differences with 3D map.
- Digital forest is an exciting complement to normal camera footage.
- The digital forest is questioned when it comes to how close it recreates reality.

5.3 Final Design - Redesign of 3D Twin

With the evaluation as a base, a redesign was made on the prototype. Reworked parts included the Landscape Material, forest ground, paths and the PCG. This was done to improve the visual fidelity of the virtual forest. A problem area identified in the thematic analysis was similarity of the virtual and physical forest. The landscape material and forest generation was hence improve for a more realistic result.

5.3.1 Landscape Material

The redesign took use of a new landscape material. This allowed for painting different material layers for different type of grounds, which was not possible for the first material. An example is presented in figure 5.4. Two different textures are being used as material, with different foliage being spawned on top.

Figure 5.4: Painted landscape layers meeting.

5.3.2 Paths

The first prototype left some questions of the landscape creation unanswered. Creation of paths was one, since the landscape material did not have a functional way of creating them. Hence, another material was decided for use, which could create paths for splines. The result of the path creation can be seen in figure 5.5.

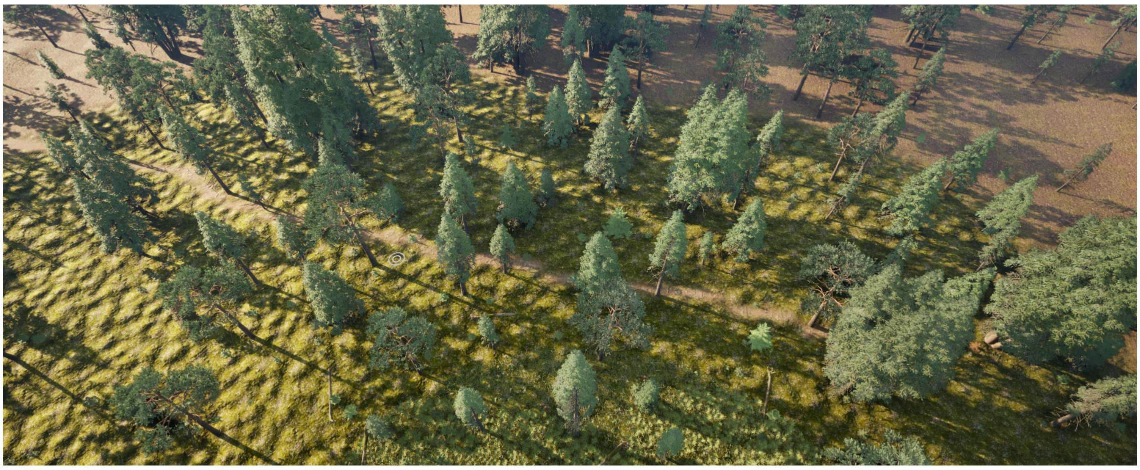


Figure 5.5: Path created through a spline on the landscape.

5.3.3 PCG

The generation of vegetation through PCG was also redesigned. Vegetation as trees and objects like stones were changed. The results of the this can be seen in figure 5.6.

Figure 5.6: Redesign of PCG with new meshes in the forest.

5.3.4 Cliffs

Cliff generation was redesigned to be editable after being spawned. The result of these can be seen in figure 5.7.

Figure 5.7: Redesign of PCG with editable cliffs spawned in the right locations.

5.4 Key Factors for Improving Understandability

The aim of this thesis have been to create visualizations that can help viewers get a better understanding of orienteering on TV. Key factors for improving the comprehensibility have been identified as the following:

- **Provide visual cues to improve the understandability of signs.**

With orienteering taking use of symbols that can be categorized as index signs within visual semiotics, these signs need to be deciphered by the viewer. By helping the viewer through visual cues, the understandability can be improved. User tests showed that terrain shadowing, which provides depth to the images, helped all viewers understand the height differences of a map. Both novice and expert viewers appreciated the visual cues givcen. While a normal orienteering map has symbols which needs to known by the viewer to understand, shadows is an universal symbol. This connection to the real world can helped viewers understand the signs of an orienteering map.

- **Real world connections for viewers without experience.**

The visual cues discussed above are an example of providing real-world connections to a viewer. The shadows behind a hill give an everyday example of what they are looking at. Further, using 3D Twin forest together with a map can equip the viewer with the tools needed for even better understanding. By seeing an example of objects in the forest next to a map, physical-world connections between objects and signs are given to the viewer. Viewers that do not understand symbols on an orienteering map, can here be given the chance of understanding. The symbols of a map could here be deciphered through real world connections using the 3D Twin.

- **Balance between emotions and understandability.**

A TV broadcast needs to be both understandable and exciting. By taking use of the medium best suited for the ends needed, a balanced mix can be achieved. Providing users with both emotions from the forest and understandability from a map is key for a compelling broadcast. While the perfect mix has not been established in this thesis, the idea could be important for further work to take into consideration.

6

Discussion

The chapter provides discussion of the design process and results of the project. Data analysis, visual semiotics and accessibility versus excitement is further touched upon. Lastly, the research question and future work is mentioned.

6.1 Process

The design process of this started in an exploration phase. Brainstorming around possible areas of development were of importance for establishing the working direction of the thesis. By exploring early ideas, possible early bottle-necks could be avoided, if any. This due to the technical nature of the thesis, where real-world data was discussed to be used. The exploration phase showed good results and no re-direction of the project was needed.

6.1.1 UX Lifecycle vs Double Diamond Design Process

Different design processes were taken into consideration for the project. These methods are not unlike each other and could take use of the same kind of methods for prototyping, evaluation and design work.

Both these design processes has been kept in mind when designing. Since the project differs from traditional UX design, where interaction between user and interface is usually physical in some way, the need for a combination was justified. With user only viewing the final design, some parts can not be tested as for traditional UX. Error tests with navigation through an interface were not a suitable test for example. By having another type of design process to lean on, design work could proceed without having to gets stuck at one step of the process.

Brainstorming was done within the project team. Instead, the use of external resources could have been interesting here. By doing user tests as a starting point for the thesis, early problem areas for viewers could have been established and focused on. Further early ideas could have been explored that the project team missed. The problem statements now arise from a small group of people with expert knowledge around orienteering broadcast. Taking use of novice viewers from the start could have provided an interesting data layer, as a base for the direction of the thesis.

This was done for the re-design of the prototype. User input was gathered and analyzed for decision making based on the viewers experiences. The direction chosen here was to improve the authenticity of the prototype. While this could improve the visual fidelity and emotion provided by the prototype, the case might not be the same for the understandability. This will be discussed further in the next segment.

6.2 Thematic Analysis

The data collection gave rise to themes within the answers of the interviewees. The interpreted themes further helped improving the final design of this project. On the positive note, the analysis showed that the test viewers did get a better understanding of the orienteering map. Even novice viewers could understand height differences which was not the case for the normal, flat map.

However, the map contains a number of other symbols. Novice viewers could still not grasp the reality of these where stones, cliffs and other symbols could not be deciphered. The 3D map does not provide help for the viewers to understand any of these symbols. This is an area for possible improvement. How can other symbols be shown in an understandable way? Some expert viewers suggested adding 3D objects on top of the map. Stones and undergrowth in marshes could be added to show what the symbols actually refer to. This would be a great way to give the viewers visual cues to make connections to reality.

Expert viewers showed concern for the digital forest not looking exactly like the physical forest. This was a concern since it could give the viewers the wrong picture of what the runners experience during their races. Whilst the idea is reasonable, there might be positives to the digital forest not looking exactly like its origin. The viewers will easier understand what is a fake, digital forest. Some of the interviewees, especially the elder, thought all pictures they saw were real.

On the other hand, having the audience believe that computer generated images are real is a compliment to the creator. Further, a more visually pleasing and coherent story can be told to the viewer if all images match. Merging from filmed footage to the digital forest can happen seamlessly without the audience noticing a big change. Since all the expert interviewees questioned the realness of the fake forest, effort was made to make it more realistic. The question is what is more enjoyable and understandable for the viewer, which is an area for further research.

6.3 Visual Semiotics

Orienteering maps uses indices that points to factual connections. Hence, the viewer needs experience to make the connections to the physical world. Without experience of orienteering, these connection might be very hard to make. What does a black point mean? What does a brown curve represent?

Here, the visualisations of this project can come to the rescue. As a middleman between the real world and the image shown to the viewer, the visualizations can deliver this connection. By showing a fake forest next to symbols on a map, associations to these index signs can be made. Instead of needing experience of orienteering maps and what they represent in reality, it can be seen in the digital forest.

Further, the 3D map provides visual cues to support the understandability. Instead of having to decipher what a brown line means, the viewer can see shadows form around a hill. They can see pits hollowing out the ground catching shade inside itself. These are tells everybody can understand, rather than the symbols of an orienteering map.

Further effort can be made here. With plenty of symbols on maps still not providing new visuals cues for the viewer to make understanding of, there is room for improvement. Providing cues for height differences using shadow is one thing. Shadows are a natural addition to an image and something everybody can understand. But, how does one mediate the symbol for a stone or a cliff? Is it enough to simply put a 3D object of that sort on top of the symbol? And how is that done without occluding symbols at the same time? Is there another, more effective way to help viewers understand an orienteering map?

6.4 Accessability Versus Excitement

While focusing on the improving the understanding of the broadcasts, excitement is and has been another important factor in the thesis. Creating visuals that can capture viewers' interest is important for the storytelling. When showing multiple hours of orienteering, this can be extra important as attention spans shortens with the daily use of short-form social media.

Viewers showed excitement during the evaluation. Expert viewers were impressed by the improvement from other orienteering broadcasts they had seen. Being able to see the map in a new way and experiencing the forest that couldn't be showed before was a thrilling experience.

The balance of thrill and understandability can be important. While some viewers found the forest view very exciting, some saw problems in it being too far from reality. Taking use of different mediums for different reasons could be the optimal way. While the 3D map provides a great understanding for the course and the map, the digital forest could create more emotions for the viewer. Depending on use-case and scenario in the broadcasts, either can be used for a different outcome.

6.5 The Designers' World-view

The origin problem area for this thesis was described as a wicked problem. With more than one possible solution available for an end results the *Weltanschuang*, or world-view, of the designer will play a great role. Without the designer being aware of this, it could cause issues.

This project was born on the world view of a designer. By having watched orienteering broadcasts and noticing a possible understandability gap, the project was created. Further, 3D visualization was introduced as a medium due to the *Weltanschuang* of the same designer. Was this the right choice that led to the best solution possible?

As a wicked problem states for its foundation, there might not be a way to know. More than one possible solution were available in the design space, and one was attained. But with the results showing both excitement and improved understandability, at least the designer was not wrong. By taking in account both the positive and negative contribution they can have on the solution, the designer has tried to minimize the latter. The end result has hopefully furthered the design space by a millimeter or two, where improvement of the understandability of orienteering broadcasts has been achieved.

6.6 Key Factors for Improving Understandability

As presented in the results, the following key factors were identified through the design process. Discussion regarding these follows:

- **Provide visual cues to improve the understandability of signs.**

Through visual aids like terrain shadowing, the understandability did improve during the user tests. Even critical users, or viewers, without experience of orienteering maps could understand the height differences sometimes. More of these cues would be interesting to implement.

- **Real world connections for viewers without experience.**

Without experience of orienteering maps or the nature they reference to, the maps can be hard to decipher. By providing these connections understandability could be improved, especially for the inexperienced.

- **Balance between emotions and understandability.**

The balance of emotion and understandability have been shown to correlate. By understanding the thing your looking at, the enjoyment have been showed to improve. While this can not be cemented by the work of this thesis, the idea could be important for these kinds of broadcasts. Being made for both enjoyment and to be understood, the two have to synergize. How this is done in an effective way is for further work to establish.

Further user testing would be interesting to cement that the key factors do increase understandability. While the first two are in line with visual semiotics, with visual cues and real world experiences being important, the third factors could need more user input. Where the right line is drawn between emotions and understandability is not defined either, which could be a interesting topic for TV broadcasts.

6.7 Future Work

Future work has been touched upon in this discussion chapter. Interesting areas here will be further developing the visual cues provide by images. By developing visual cues for every symbol on an orienteering map, the understandability could improve significantly. How this can be done in a natural way, without taking too much attention from the map itself can be key for the end result.

For the prototype of the digital forest, it has come a long way. Interesting areas here are taking further use of real life data inside of the virtual twin. GPS-data could be used to drive animations of characters in the forest. Other types of data could be used for forest and vegetation generation. Manual labor for paths and cliffs could be automated for easier recreation of new forests.

6.8 Ethical Issues

Working with orienteering maps and courses can be a delicate task. Since maps and courses are kept secret before competitions, this project has not been an exception. By taking use of older and public maps, the new parts could be kept hidden. With made-up example courses the viewers could be given a relevant orienteering course to look at, without showing test subjects secret courses.

GPS-data has yet to be implemented into the digital twin. By taking use of third party data from GPS distributors, live-tracking of runners could be possible inside of the digital twin. The data handling could here be important to take into consideration. The data handled should not be of the most confidential nature, but the rules and regulations provided by the distributors has to be examnied and followed.

If further animations made in the digital twin would contain human characters, these could be made to look like the runners of the competitions. Further consent from these people would be needed, to create digital twins of the humans as well. A possible option here would be using a generic character for both genders, or a male and female character for the different gender-classes in orienteering.

7

Conclusion

This thesis was grounded in the belief that 3D visualizations can help viewers get a better understanding of orienteering on TV. Through a digital twin of a forest, and a three dimensional orienteering map the understandability for orienteering was improved. Novice viewers received a better understanding of the terrain, where they had not been able to decipher the map before. Expert viewers enjoyed the evolvement of the map, shown in a more intuitive way.

The digital twin introduce a new way of visualizing orienteering on TV. By recreation of physical landscape inside of Unreal Engine, every part of a forest could be visualized to the audience. The result was found as an exciting complement to where normal cameras can not reach.

Further, key factors for improvement were defined based on the findings of the design process. These key factors are aimed to define important areas to focus on for future work in similar fields. By providing viewers visual cues in imagery shown, understandability can be improved. To help them understand maps for intuitively, real world connections can be provided for viewers without the experience. Lastly, a balance between comprehensibility and emotion is key. Viewers can benefit positively by both experiencing visuals that speak to their feelings and are easily understandable.

The project has had a very practical design process, with plenty of technical contributions. The ability to re-create Swedish landscapes through height data have been achieved. Hence, a both theoretical and practical working of way of creating digital twins have been showed.

By utilizing orienteering maps, the digital twins fidelity have been showed to be able to re-create reality very closely. Forest of different density, marshes and open areas can be generated using PCG to reassemble the physical world. Using 3D scanned assets from real, Nordic forests the nature has been captured in the virtual one.

With the help of the digital forest, the understandability for orienteering have shown to improve. Key factors for this cause have been established as the following:

- **Provide visual cues to improve the understandability of signs.**
- **Real world connections for viewers without experience.**
- **Balance between emotions and understandability.**

These bring a theoretical contribution from the thesis. By having their base in visual semiotics, the factors cements these theories further. The tests performed here have shown that visual cues does help the viewer interpret images better. By providing real world connections, experience can be gained for those who do not possess it.

By implementing these into relevant fields, understandability could be improved for several areas. Within television, visualization could be used for a number of sports to create exhilarating visuals. Especially the ones with a playing field as undefined as orienteering, could all benefit from taking use of the findings of this design thesis.

Bibliography

[1] Unreal Engine, *The weather channels new studio brings immersive mixed reality to daily live broadcasts*, 2025. [Online]. Available: https://www.unrealengine.com/en-US/spotlights/the-weather-channel-s-new-studio-brings-immersive-mixed-reality-to-daily-live-broadcasts.

[2] M. Page and A. Moere, "Towards classifying visualization in team sports," in *International Conference on Computer Graphics, Imaging and Visualisation (CGIV'06)*, 2006, pp. 24–29. DOI: 10.1109/CGIV.2006.85.

[3] B. Bal and G. Dureja, "Hawk eye: A logical innovative technology use in sports for effective decision making," *Sport Science Review*, vol. XXI, Apr. 2012. DOI: 10.2478/v10237-012-0006-6.

[4] Sony, *Making sports more exciting through visualization technology*, Read 26 February 2025, 2021. [Online]. Available: https://www.sony.com/en/SonyInfo/technology/stories/entries/Hawk-Eye/.

[5] J. Spitz, J. Wagemans, D. Memmert, A. M. Williams, and W. F. Helsen, "Video assistant referees (var): The impact of technology on decision making in association football referees," *Journal of Sports Sciences*, vol. 39, no. 2, pp. 147–153, 2021. DOI: 10.1080/02640414.2020.1809163.

[6] W. Gaver, "What should we expect from research through design?" In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ser. CHI '12, Austin, Texas, USA: Association for Computing Machinery, 2012, pp. 937–946, ISBN: 9781450310154. DOI: 10.1145/2207676.2208538. [Online]. Available: https://doi.org/10.1145/2207676.2208538.

[7] R. Buchanan, "Wicked problems in design thinking," *Design Issues*, vol. 8, no. 2, pp. 5–21, 1992, ISSN: 07479360, 15314790. [Online]. Available: http://www.jstor.org/stable/1511637 (visited on 02/26/2025).

[8] H. W. Rittel and M. M. Webber, "Dilemmas in a general theory of planning," *Policy Sciences*, vol. 4, no. 2, pp. 155–169, 1972. DOI: 10.1007/BF01405730. [Online]. Available: https://escholarship.org/uc/item/01v4t1c9.

[9] e. a. Cooper Alan, "About face : The essentials of interaction design," in *The UX Book: Process and Guidelines for Ensuring a Quality User Experience*. John Wiley Sons, Incorporated, 2014. [Online]. Available: https://ebookcentral.proquest.com/lib/chalmers/detail.action?docID=1762072.

[10] A. Marcus, "Principles of effective visual communication for graphical user interface design," in *Readings in HumanComputer Interaction*, Morgan Kaufmann, 1995.

[11] M. Hassenzahl and N. Tractinsky, "User experience - a research agenda," *Behaviour & Information Technology*, vol. 25, no. 2, pp. 91–97, 2006. DOI: 10.1080/01449290500330331. [Online]. Available: https://doi.org/10.1080/01449290500330331.

[12] M. Hassenzahl and N. Tractinsky, "Experience design - technoplogy for all the right reasons," in Morgan Claycool Publishers, 2010.

[13] J. Wideström, "A seeing place," Ph.D. dissertation, Chalmers University of Technology, 2020.

[14] A. R. Teyseyre and M. R. Campo, "An overview of 3d software visualization," *IEEE Transactions on Visualization and Computer Graphics*, vol. 15, no. 1, pp. 87–105, 2009.

[15] T. W. Cornelius Malerczyk Konrad Klein, "3d reconstruction of sports events for digital tv," *UNION Agency Science Press*, 2003. [Online]. Available: https://dspace.zcu.cz/items/557cda07-2df5-4c41-9bc1-7e88c1c9007b.

[16] T. Schenk, "Introduction to photogrammetry," Department of Civil, Environmental Engineering, and Geodetic Science, The Ohio State University, Tech. Rep., 2005.

[17] e. a. Tong Wu Yu-Jie Yuan, "Recent advances in 3d gaussian splatting," *Computational Visual Media 10*, 2024.

[18] G. Thomas, "Sports tv applications of computer vision," in *Visual Analysis of Humans: Looking at People*, T. B. Moeslund, A. Hilton, V. Krüger, and L. Sigal, Eds. Springer London, 2011, pp. 563–579. DOI: 10.1007/978-0-85729-997-0_28. [Online]. Available: https://doi.org/10.1007/978-0-85729-997-0_28.

[19] R. Hartson and P. S. Pyla, "A ux process lifecycle template," in *The UX Book: Process and Guidelines for Ensuring a Quality User Experience*. Elsevier, 2012, ch. 2.2, ISBN: 978-0-12-385241-0. [Online]. Available: https://app.knovel.com/hotlink/khtml/id:kt00BP23C1/ux-book-process-guidelines/ux-process-lifecycle.

[20] W. Bouwer and F. Human, "The impact of the uncanny valley effect on the perception of animated three-dimensional humanlike characters," *The Computer Games Journal*, vol. 6, pp. 185–203, 2017. DOI: 10.1007/s40869-017-0041-8. [Online]. Available: https://doi.org/10.1007/s40869-017-0041-8.

[21] B. Leurs and I. Roberts, *Playbook for innovation learning*, 2018. [Online]. Available: https://www.nesta.org.uk/toolkit/playbook-for-innovation-learning/.

[22] P. M. Nardi, "Doing survey research - a guide to quantitative methods.," in Routeledge, 2018, ch. 1.

[23] M. Bearman, *Focus on Health Professional Education: A Multi-Professional Journal*, vol. 20, no. 3, pp. 1–11, 2019. [Online]. Available: https://search.informit.org/doi/10.3316/informit.002757698372666.

[24] O. C. Robinson, "Probing in qualitative research interviews: Theory and practice," *Qualitative Research in Psychology*, vol. 20, no. 3, pp. 382–397, 2023. DOI: 10.1080/14780887.2023.2238625. [Online]. Available: https://doi.org/10.1080/14780887.2023.2238625.

[25] R. A. POWELL and H. M. SINGLE, "Focus groups," *International Journal for Quality in Health Care*, vol. 8, no. 5, pp. 499–504, Jan. 1996, ISSN: 1353-4505. DOI: 10.1093/intqhc/8.5.499. [Online]. Available: https://doi.org/10.1093/intqhc/8.5.499.

[26] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, 2006. DOI: 10.1191/1478088706qp063oa. [Online]. Available: https://www.tandfonline.com/doi/abs/10.1191/1478088706qp063oa.

[27] R. E. Boyatzis, "Transforming qualitative information: Thematic analysis and code development," in Sage Publications, 1998.

[28] Lantmäteriet, *Markhöjdmodell nedladdning, grid 50+*, 2025. [Online]. Available: https://www.lantmateriet.se/sv/geodata/vara-produkter/produktlista/markhojdmodell-nedladdning-grid-50/.

[29] C. Commons, *Attribution 4.0 international*, 2013. [Online]. Available: https://creativecommons.org/licenses/by/4.0/.

[30] Lantmäteriet, *Markhöjdmodell nedladdning*, 2025. [Online]. Available: https://www.lantmateriet.se/sv/geodata/vara-produkter/produktlista/markhojdmodell-nedladdning/.

[31] Lantmäteriet, *Sweref 99, projektioner*. [Online]. Available: https://www.lantmateriet.se/sv/geodata/gps-geodesi-och-swepos/Referenssystem/Tvadimensionella-system/SWEREF-99-projektioner/.

[32] Lantmäteriet, *Komma igång i geotorget*, 2025. [Online]. Available: https://www.lantmateriet.se/sv/geotorget-produktstod/guider/komma-igang-i-geotorget/.

[33] E. Games, *Landscape technical guide*, 2025. [Online]. Available: https://dev.epicgames.com/documentation/en-us/unreal-engine/landscape-technical-guide-in-unreal-engine?application_version=5.3.

[34] I. O. Federation, *Mapping*, 2025. [Online]. Available: https://orienteering.sport/iof/mapping/.

[35] E. Games, *Procedural content generation overview*, 2025. [Online]. Available: https://dev.epicgames.com/documentation/en-us/unreal-engine/procedural-content-generation-overview.

[36] NVIDIA, *Nvidia dlss*, Hämtad 2025-04-29, 2024. [Online]. Available: https://developer.nvidia.com/rtx/dlss?sortBy=developer_learning_library%2Fsort%2Ffeatured%3Adesc%2Ctitle%3Aasc&hitsPerPage=6.

A
Appendix 1

Intervju

Warm-up questions:

Participants respond best when they are enjoying themselves, do not feel threatened or defensive and are clear about what they are being asked. s. 4

Vad har du för erfarenheter när det kommer till sporten orientering?

Har du tidigare tittat på orientering på TV?

Om Ja: Vad var din upplevelse av sändningen?

Om Nej: Hur kommer det sig?

Jag ska nu visa dig exempel på orienteringssändningar. Tänk dig att du sitter hemma i vardagsrummet och slår på TVn. SVT 1 är på och du ser att en sändning av orientering precis har börjat. Kommentatorn förklarar att det är en sändning av en orienteringsvärldscup från Idre Fjäll. (De ska nu visa upp banan som kommer springas denna tävling, kanske skkippa denna?

Visa upp hela klippet, sen gå tillbaka till specifika delar och ställ frågor.

Kan du beskriva vad du precis såg?

Vid överflygning:

Kan du förklara vad detta försöker beskriva?

Varför tror du dessa texter visas i skogen?

När karta visas:

Kan du förklara vad denna symbol är för något? (Peka på höjdparti).

Kan du förklara vad denna symbol är för något? (Peka på sänka)

Kan du förklara vad denna symbol är för något? (Peka på sten)¨

Om vägval visas:

Figure A.1: Interview questions.

B

Appendix 2

The following link provides a download for Appendix B.

https://drive.google.com/file/d/1ScGUjIKml-dUyhWk1Ukrkds2j3hcnGzX/view?usp=drive$_link$

C

Appendix 3

Vid överflygning:	**Teman:**	**Teman:**
Kan du beskriva vad du precis såg?		**Good overview**
Alla förstår att det är området de springer i som visas		
De förstår också att mål, start osv visas		
Önskas mer information vid dessa punkter, publik, osv		
Varför tror du dessa texter visas i skogen?		
Alla förstår att de visar upp mål, start osv för att placera dem i verkligheten		
När karta visas:		
		Exciting feature
de flesta förstår vad kartan symboliserar, vad som är en höjd vad som är en svacka		**Great understandability**
denna 3d karta föredras framför en 2d karta. ger lite bättre känsla för terrängen, kan faktiskt se vad som går upp och ne		**Improvement from 2D map**
även novistittare förstår vissa höjdformationer, utan att säga sig ha sett en orienteringskarta förut. en person kan förstå höjderna		
när de visas i vinkel medans en annan kan förstå höjder och sänkor när de visas ovanifrån, eller när det är mindre höjder och inte stora berg		
Om vägval vis		
syns tydligt vad som går upp och ned		
får en annan känsla av vad de upplever i skogen		
vissa tecken kan döljas på 3d karta, beroende på vinkel		
förstår att olika vägval väljs beroende på hur platt det är att gå runt		
skogsvy igen:		
övergång från karta till skog är snygg		**Cant replace real cameras - complement**
bra att kunna ser hur det ser ut i terrängen, från kartan		**Good to combine with map for understandability**
Kan man visa bara objekt på kartan innan, för att tydligare förstå		**Forest view is exciting, but perhaps too far from reality**
skogsvyn är spännande då den döljer hemligheter		
en person förstår ej att vyn inte är på riktigt		
skogen visar hur det ser ut och vart man ska springa, vart de är planare		
Är det någon del av denna video som sticker ut för dig? Som hade gjort dig extra exalterad		
3d kartan		
Skogsvy är cool, men är inte helt lik verklighet. denna kan behövas göra mer lik, och bör inte ersätta vanliga kameror		

Figure C.1: Thematic Analysis