Høgskolen
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Technological Substrate for the GOGREEN VR Showcase

GOGREEN VR Showcase

Oppdragsrapport nr. 18 - 2023

Utgivelsessted: Elverum

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Oppdragsrapport nr. 18-2023

ISBN online utgave: 978-82-8380-424-9

ISSN: 2535-4140

Sammendrag

Denne rapporten ble utviklet som en del av forskningsprosjektet «GoGreenRoutes». Nærmere bestemt, rapporten beskriver aktiviteten tilknyttet oppgave 6.4 (arbeidspakke 6), som har som mål å designe og lage en Virtual Reality (VR) installasjon for å øke bevisstheten om miljøutfordringene knyttet til urbanisering, formidle fordelene ved aktivitet i naturen, og fremkalle følelser av tilknytning til lokale steder. Installasjonen vil bli vist i alle byene som inngår i GoGreenRoutes. I denne rapporten gir vi først en overordnet begrunnelse for arbeidet, med en kort oversikt over generelle begreper knyttet til VR-teknologi og teknologiens potensial for å formidle og fremme naturopplevelser. Vi beskriver deretter prosedyrene og instrumentene som ble brukt for å utvikle installasjonen, samt maskinvaren som ble brukt for å levere dette. Til slutt presenteres en oppsummering av tre "kick-off events" som ble gjennomført i tre norske byer med hensikt å lansere installasjonen, samt å teste den i forbindelse med et offentlige arrangement.

Emneord: virtuell virkelighet, virtuell natur, bevegelsessensorer

Oppdragsgiver: Den Europeiske Union, Horizon 2020 "research and innovation programme" (grant agreement No 869764).

Abstract

This report was developed as a part of the research project 'GoGreenRoutes'. More specifically, the report describes the activities of Task 6.4. (WP6), which aims to create a Virtual Reality (VR) Experiential Showcase to raise awareness about urbanization's environmental challenges, convey benefits of activity in nature, and elicit feelings of attachment to local places, which will be displayed in all collaborating cities. We first provide the overarching rationale for the task, with a brief overview of general concepts connected to VR technology and its potential to mediate and promote nature experiences. We will then describe in detail the procedures and instruments used to develop the VR scenario, as well as the hardware used to deliver it. Finally, we present a summary of three "kick-off events" conducted in three Norwegian cities, which had the purpose of launching the Showcase and to test it in the context of public events.

Keywords: Virtual reality, virtual nature, movement trackers

Financed by: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869764. The sole responsibility for the content of this document lies with the GoGreenRoutes project and does not necessarily reflect the opinion of the European Union.

Preface

This report was developed as a part of the research project 'GO GREEN: Resilient Optimal Urban natural, Technological and Environmental Solutions' (GoGreenRoutes; https://gogreenroutes.eu/), funded under the European Commission's Horizon 2020 programme. The contents of this reports was used as an internal document in the prosject to share the technological advances of task 6.4. The VR showcase that this work is based upon was created through an interdisciplinarry effort between different faculties and institutes at the Inland Norway University of Applied Sciences and University of South-Eastern Norway. The project grouped involved a programmer, 3D artist, exercise physiologist, and a proffessor in public health. The report describes the workflow towards the final product, and the issues along the way, as well as the outcomes of a pilot test in three Norwegian cities. Some modifications to the showcase after the pilot is to be expected, before the it goes on tour to several european cities (Burgas, Lahti, Limerick, Tallinn, Umeå, Versailles).

The Government's standard agreement for research and development assignments from February 2012 forms the basis for the project. The research is conducted in accordance with recognized scientific and ethical principles. Quality assurance in the project is carried by Research Ethics Committee of the Inland Norway University of Applied Sciences and the privacy representative of University of South-Eastern Norway.

Contents

1. Background

1.1 Overarching context and objective

GoGreenRoutes designed and created a highly immersive VR Experiential Showcase to raise awareness about urbanisation's environmental challenges, to convey benefits of activity in nature, and to elicit citizens' feelings of connectedness and belonging to local places. The VR Experiential Showcase will be displayed in all Cultivating Cities (D6.5). A team of researchers from the Inland Norway University of Applied Sciences (INN) is leading the development of the Showcase and will coordinate the roadshow across the Cultivating Cities. The VR Experiential Showcase uses state-of the art technologies and devices, powered by a high-performance computer. It is developed by a highly transdisciplinary team composed of a 3D artist (Fred Fröhlich, Associate Professor), a computer scientist (Ole E. Flaten, Ph.D. candidate), a sport scientist (Sigbjørn Litleskare, Associate Professor), and a professor of health sciences (Prof. Giovanna Calogiuri) who worked together to ensure a highly realistic and physically engaging experience for the users.

Through the VR Experiential Showcase, people can immerse themselves in a virtual world. Motion trackers placed on the users' waist and ankles allow them to explore the virtual environment by actually moving in it (walk-in-place), almost like they would do in the real world. For this purpose, when using the Showcase, the user is placed on a soft mat of about 1-square meter– the difference between the hard floor and the softer mat is easily perceived, acting as an "invisible barrier" to inform the participant on where to stand. However, the installation was developed in a way that it is still highly accessible for individuals who, for different reasons, cannot or do not want to stand and balance on their feet. In these cases, an alternative is provided that allow people to explore the virtual world whilst sitting on their own wheelchair or on a swivel chair by using a hand-held controller or moving the ankle-trackers with their hands. The experience commences in a city setting (a 3D reproduction of Hamar, Norway) but the users will soon encounter a magic portal or gateway, which takes them to a fascinating parallel dimension where nature took over the city. People can explore and interact with the virtual world, viewing the tall trees, the complexity of the grass and the undergrowth, hearing the sounds of birds in the natural soundscape. The virtual experience is predicted to remind us of the importance of appreciating the local green spaces and nature views in our cities as a means to recover mentally.

BOX 1. DESCRIPTION OF THE TASK (AS IN THE GRANT AGREEMENT)

Objective: To design and create a multi-sensory VR Experiential Showcase to raise awareness about urbanization's environmental challenges, convey benefits of activity in nature, and elicit citizens' feelings of attachment and belonging to local places.

Description: Task 6.4 VR Experiential Showcase (M13 - 36) [Task Lead: INN; Partners: Helix, NUIM, all Cultivating Cities]: Develop immersive virtual natural environments that will be used in the Showcase (from Task 6.1). Construct the technological substrate for the Showcase (VR system displaying immersive images and sound; manually driven treadmill to simulate physical activity; mega-screen to display the scenes viewed in the VR systems. Using a brief pre-/post- exposure mood survey citizens' experiences with the VR Experiential Showcase and the extent to which the experience led to enhanced feelings of connectedness with nature will be evaluated. The VR tools will be pilot tested with a variety of age-groups to ensure their viability and effectiveness.

Deliverable: Display of VR Experiential Showcase in all Cultivating Cities

Figure 1. 3D artist Fred Fröhlich tests the VR Experiential Showcase in his office.

Credits: Fred Fröhlich

1.2 Virtual Reality to reconnect people to nature

Today, we are often exposed to views of nature through different digital means, such as computer screens or "digital windows" (large screens that simulate window views, often on natural landscapes). Modern mobile phones allow us to capture, store, and easily access pictures of our favourite places. In recent times, increasing interest has been directed towards Virtual Reality (VR) technology as a way of delivery more immersive, vivid, and effective nature experiences. Litleskare et al. (2020) introduced the concept of immersive virtual nature (IVN), referring to immersive VR technologies that specifically provides the illusory perception of being enclosed within and interact with a natural environment. The increasing interest in IVN technology, either for recreation, self-care, or even clinical treatment, is on the rise (see e.g., White et al, 2019), and prompts the question on the extent to which this technology can provide benefits similar to those provided by interactions with actual nature. Accumulating research shows that, although it is incapable of delivering the full and complex sensory input that characterize nature experiences (weather, smells, high levels of biodiversity, etc.), not only can IVN provide psychophysiological benefits that emulate (to a limited extent) those experiences in actual nature (see e.g., Browning et al., 2020), but it can also provide greater benefits compared with nature experiences delivered through less immersive digital means (Liszio & Masuch, 2018; Yeo et al., 2020). This indicate that characteristics of digital technologies influence the fidelity of the experience as well as the users' subjective perceptions, which in turn are fundamental in determining the magnitude of the benefits (see chapter 2.2.1). Beyond this, evidence indicate that IVN experiences can foster people's feelings of connectedness with the natural world and even encourage them to visit actual nature (Brambilla et al., 2022; Calogiuri et al., 2022). This suggests how the utility of IVN technology may go beyond that of simulating human-nature interactions, bearing a great potential as a means for the promotion of place- and nature- attachment (Calogiuri, Litleskare, & MacIntyre, 2019).

Nature connectedness is a general term referring to a person affinity for the natural world, such as the extent to which they identify as part of and care for nature (Schultz, 2002). People who feel more connected with nature often report greater engagement in pro-environmental behaviours (Mackay & Schmitt, 2019; Whitburn et al., 2019) and overall happiness, vitality, and life satisfaction (Capaldi et al., 2014; Pritchard et al., 2019). Importantly, the relationship between people's affinity for nature seem to be independent of the amount of time they spend in nature (Richardson et al., 2021), although people who have greater affinity for nature tend to spend more time in nature (Calogiuri, 2016). Considering these benefits, it is pertinent to understand how we can effectively foster people's nature connectedness. Experiences in nature, especially during childhood, is paramount for building people's nature connectedness as adults (Calogiuri, 2016; Rosa et al., 2018; Soga et al., 2020; Ward Thompson et al, 2008). However, in adult populations, even brief experiences in nature such as tree-planting, nature walks, and mindfully noticing nature in one's daily life, can increase nature connectedness, and such effects can ben long-living when such nature experiences are repeated over time (Sheffield et al., 2022). As the opportunities for interacting with nature are globally decreasing, this technology bares the potential of contributing to fostering people sense of connection with nature. A recent meta-analysis by Sheffield et al. (2022) highlights that digitally mediated experiences of nature can elicit increased nature connectedness to a similar magnitude as experiences in actual nature. More specifically, growing research shows that exposure to IVN can be effectively increase people's feelings of nature connectedness (Chan et al., 2021; Leung et al., 2022; Sneed et al., 2021; Yeo et al., 2020).

BOX 2. WHY VIRTUAL NATURE?

While the concept of virtual nature may appear as the ultimate paradox, and established that (when possible) interactions with actual nature are preferrable, virtual nature has been proposed as a way to integrate more frequent nature experiences in people's everyday life, as well as providing access to nature to individuals form whom (for various reasons) it is not recommended to dwell outdoors.

See Prof. Calogiuri explaining how virtual nature can be a means of health promotion at TEDxDrammen

1.3 The issue of urban nature connectedness

As most people live in urban settings, and urban population is on the raise, the opportunity to interact with uncontaminated or "wild" nature are globally decreasing. In this respect, increasing interest have been lately given to the importance of urban nature (i.e., elements of nature embedded within the urban landscape, such as threes, green areas, view on natural landscapes, etc.) as a way for people to interact and connect with the natural world (Schönbach et al., 2022). Research demonstrated that the overall time spent in nature, rather than the frequency of nature visits, is associated with higher levels of urban nature connectedness (Schönbach et al., 2022, Cleary et al., 2020). However, recent analyses suggests that, especially in urban contexts, being passively exposed to views of nature may not be enough in supporting people's feelings of connectedness with urban nature, while it is important that people notice and engage with the nature around them (Sheffield et al., 2022). Indeed, initiatives that encourage citizens to notice and engage with the nature in their living environment have been proven effective in increasing urban nature connectedness (McEwan et al., 2019; McEwan et al., 2021; Passmore et al., 2022; Richardson & Sheffield, 2017). Hence, when using IVN as a tool to promote and foster urban nature connectedness, it is important that IVN experiences focus on raising the users' awareness of urban nature and their benefits.

1.4 Virtual Reality

Virtual Reality (VR) is a digital technology that provides the illusion of being inside and interact with a virtual world. In more technical terms, VR has been defined as "A medium composed of interactive computer simulation that senses the participant's position and actions and replaces or augments the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation (a virtual world)" (Sherman & Craig, 2003; p. 13). In recent years, the public has become increasingly familiar with this technology due to the introduction in the marker, prompted by the gaming and entertainment industry, of relatively inexpensive consumer-oriented head-mounted displays (HMDs), also known as "VR goggles" or "VR masks". These devices provide a 360° vision of a virtual environment while at the same time obstructing the vision of the actual surrounding environment, allowing a person to immerse themselves in a virtual world. They can also be combined with different types of sensors, such as hand-held controllers, body sensors, and sensors connected to external devices like stationary bikes or treadmills, allowing users to move within the virtual environment.

1.4.1 Factors Influencing Virtual Reality Experiences

Interactivity

Interactivity has been defined as "the degree to which users of a medium can influence the form or content of the mediated environment" (Steuer 1992, p. 80). In other words, it relates to the extent in which the user can influence the virtual world, for instance moving objects, communicating with "virtual individuals" or other avatars, or having the possibility to influence the storyline. The levels of interactivity in a specific VR installation can vary greatly. Some simpler forms of VR (such as viewing static spherical images or videos through a HMD) may provide no possibility of interacting with the virtual environment beyond that changing view by moving one's head. More advanced and complex VR installations may provide greater levels of interactivity, such as the possibility to choose information from a limited set of options, creating or insert content, or having the virtual environment respond appropriately to the user's input.

Immersion

Immersion is considered a key component of VR technology that can strongly influence its effectiveness as well as the users' experiences. It refers to "the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant" (Slater & Wilbur, 1997; p. 3). In this sense, Immersion is directly related to the characteristics of the hardware through which a VR experience is delivered, particularly in the extent to which it provides sensory stimuli that "enclose" the user in the virtual world, for instance by impeding the view on the external (actual) premises and/or hearing of external sounds and noises. As an example, one may consider that VR experiences delivered though a television or computer screen are considered less immersive that an HMD.

Presence

While, as stated above, immersion is defined by the characteristics of the hardware through which a VR experience is delivered, presence is a person's subjective perception of being in a virtual environment (Slater & Wilbur, 1997). As such, the experience of presence may vary across users and experiences. Presence is considered pivotal to the effectiveness of the virtual environment, as it relates to the virtual environment's ability to fulfil its purpose, including providing positive outcomes, such as reduce pain (Triberti et al., 2014). In principle, systems with high levels of immersion are likely to increase the perception of presence. However, this may not always be the case, as highly immersive VR technologies are often associated with higher risk of experiencing cybersickness (see below), which may instead reduce the feelings of presence. Higher levels of interactivity are also generally believed to increase the sense of presence, as well as the user's acceptability of the VR technology (Mütterlein & Hess, 2017).

Cybersickness

Cybersickness is a specific type of visually induced motion sickness, typically characterized by dizziness, nausea and general discomfort (Kennedy, Drexler, & Kennedy, 2010). The discomfort caused by cyber sickness naturally influence the user's experience of a virtual environment. For instance, Calogiuri et al (2018) demonstrated the potential psychophysiological benefit of experiencing nature through VR was dramatically impacted by cybersickness. Furthermore, cybersickness can also reduce the sense of presence in virtual environments (Weech et al., 2019). Because of this, understanding how to deliver highly immersive and interactive experiences whilst, at the same time, avoid cybersickness is a priority for developers and researchers. To date, research a large body of evidence exists on factors that can prevent cybersickness (for instance shorter exposure time, absence of scene oscillations, limited movement lag, and use of high-end displays). Nevertheless, developers and researchers should remain aware of this factor that can so greatly (and negatively) impact the users' experiences when using VR.

2. Technological substrate of the showcase

2.1 Definition of technical concepts

360° photo and 360° video

A controllable panoramic image or video that surrounds the point from which the shot was taken. 360° photos and videos simulate being in the shoes of a photographer or cameraman and looking around to the left, right, up and down as desired.

3D mesh or polygon mesh

In 3D computer graphics and solid modelling, a collection of vertices, edges and faces that define the shape of a polyhedral object.

3D modelling

A technique in computer graphics for producing a 3D digital representation of any object or surface by manipulating polygons, edges and vertices in simulated 3D space.

Batch rendering

A technique of rendering in groups or batches. The game engine generates data using the Central Processing Unit (CPU), then sends the data to the Graphics Processing Unit (GPU) for rendering to the screen. When rendering different data objects, organizing the data into batches increases efficiency.

Frame rate

The frequency (rate) at which consecutive images (frames) are captured or displayed. The frame rate reflects how often the screen refreshes to render the digital image. It is most often measured in frames per second (FPS).

Graphics card or GPU

An expansion card for PC’s that is responsible for rendering images to the display.

Head-mounted display (HMD)

A display device, worn on the head or as part of a helmet, that has a display optic in front of each eye and a motion sensor that matches the movements of the head, allowing a 360° view of the virtual world while eliminating visual contact with the external environment.

Houdini digital asset

A custom node created with SideFX Houdini containing a series of reusable instructions—usually resulting in a 3D model. It can be loaded into other 3D applications like Autodesk Maya or Unreal Engine using the Houdini Engine plugin.

LIDAR

An acronym of “light detection and ranging” or “laser imaging, detection and ranging”—a method for determining ranges. It targets an object or surface with a laser, measuring the time it takes for the reflected light to return to the receiver.

Motion tracking

The process of digitising a user's movements into 3D space for use in computer software. This relies on detecting movement in six degrees of freedom (6DoF), corresponding to rotation (pitch, yaw and roll) around and translation (moving forward or backward, or side-ways) along the x, y and z axes.

Rendering

The process of generating a photorealistic or non-photorealistic image from a 2D or 3D model using a computer programme.

Resolution

The number of pixels in each dimension that are displayed.

XML file

An "Extensible Markup Language" file that structures data for storage and transport. The file has tags and text that represent structured information (e.g., documents, data, configuration and books).

2.2 The Virtual Scenario

General Tools and Setup:

- The rendering platform for the VR scenario is Unreal Engine (UE) 4.27. For further improving the visual fidelity we are currently updating the project to UE 5.1.
- The overall environment design is developed procedurally with SideFX Houdini; adjustable parameters are made accessible in UE through a Houdini Digital Asset (HDA).
- The city layout with buildings and roads is derived from Open Street Map (OSM) data. This allows to choose any existing urban place as template for the virtual scenario.
- Tileable facade modules are modelled with Autodesk Maya and textured using Adobe Substance Designer as well as Substance Painter.
- Buildings with a specific shape (e.g. churches) are modeled individually with Autodesk Maya.
- 3D models of trees, bushes, grass and other foliage are obtained from the Unreal Marketplace.

Creating the Basic City Environment

We decided to use OSM because it is an open-source platform and offers the possibility to edit the map data by updating shapes or assigning tags for specific locations. For instance, it is possible to add attributes like building height, roof or facade type. This information can then be read by the HDA to adapt the 3D models in the virtual scenario accordingly. We export the regions of interest from OSM as XML file and load it into the HDA. The asset allows to choose the geolocation of a specific city and interprets the existing data for creating three dimensional models representing buildings and roads.

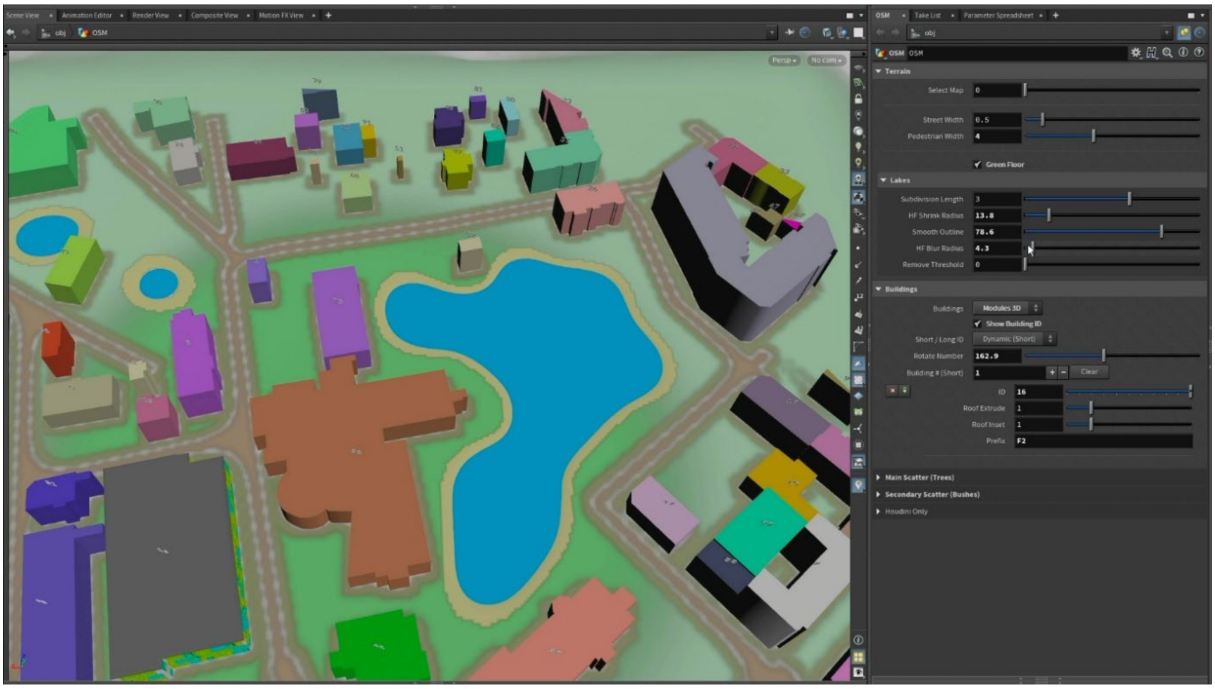

Figure 2. Basic three-dimensional city structure generated by the HDA from OSM data with parameter interface. Screenshot from SideFX Houdini.

Credits: Fred Fröhlich

In a second step additional landscape features like mountains, lakes, vegetation, debris are added. Attributes as building height, street width, lake threshold and distribution of the foliage are exposed as parameters to the interface of the HDA and can be adjusted directly in UE.

Adding Details to Buildings

The building shapes are extruded from the two-dimensional OSM-outlines and result in plain cubic shapes. Our aim was to add surface detail and increase recognizability of specific urban sites with minimal effort. Since we need to decorate a reasonable number of buildings, we were searching for a workflow with a high potential for automatisation. Firstly, we tried to capture geometry with textures using a LIDAR equipped iPad. The captured geometry shows errors especially at reflective surfaces. This could be manually fixed but the estimated time for postprocessing would not be within our budget. In addition, scanning works only in close range of approximately 10 meters—making it very difficult to capture higher buildings, so we dismissed this method. Another approach was to capture 360° photos in front of the facades with an Insta360 One X2 camera along the streets approx. every five meters. For texturing the buildings, the captured 360° photos were projected onto the facade geometry inside the 3D application. Although some buildings looked promising from the distance, stitching artefacts and perspective distortion become obvious upon closer inspection. Such optical dissonances have a negative effect on the immersion in the virtual scenario, so we dismissed this method too.

Final solution

Eventually, we decided to go further with a modular approach, which is widely used in game development. Now our HDA allows to assign different sets of premade wall modules, adjust roof shape and other attributes per building in UE. Each building has a unique ID number based on the data from OSM. We use this ID to iterate through selected buildings for defining attributes. The HDA generates then points with these attributes which will be used in UE for instancing premade wall modules.

Figure 3. Screenshot of a facade detail from our office building, captured with the 3d Scanner App on an iPad.

Credits: Fred Fröhlich

Figure 4. Capturing locations of the 360° photos (left) and the Insta360 One X2 camera with tripod in action (right).

Credits: Fred Fröhlich

Figure 5. Facades textured using the 360° photo projection method. Screenshot from Unreal Engine.

Credits: Fred Fröhlich

Figure 6. Screenshot from Unreal Engine with facade modules.

Credits: Fred Fröhlich

Modeling of Modules

To add variation within each facade type, we prepare sets of wall modules—one plain wall without windows and several others with different window designs. The modules have standardised measures and match with the texture tiling to avoid visible seams. For semi-automatically grouping and instancing, the naming of the models follows a certain convention. To achieve an optimal frame rate during playback they are modeled with a low polygon count. For a realistic look, details were applied using textures.

Texturing with Adobe Substance Designer and Painter

For texturing two techniques are used: tileable textures for seamlessly adding wall modules, and individual textures for details like window frames. To add more variation to the environment with minimal effort, we are able to change colours of existing materials easily in UE using material instances.

Growing Ivy

Selected buildings can be covered with ivy. The grooming algorithm automatically considers material definitions of the modules and avoids elements made from glass. Onto that defined area points are scattered and connected. With the shortest path algorithm splines are generated which are sweeped for branches. On this resulting geometry we then scatter leaves.

Adding Landscape Details

Integration with Houdini's height field workflow allows to

- add matching height maps from satellite data (e.g., from MapBox)
- add backdrop mountains
- procedurally define zones of different ground materials
- define zones for scattering foliage
- measure the area without roads or buildings to provide an option for creating small ponds procedurally.

Scattering Foliage

The remaining area excluding buildings, roads and ponds is the base for distributing foliage. With the HDA we scatter points on this area which will be used to attach instances of plant models in UE. We provide options to control the distribution with different noise types and to cluster groups of specific foliage. There are three different layers of foliage: Trees are the primary and secondary plants like bushes and smaller plants are grouped around the trees. Additionally, we scatter grass using the Landscape Grass Output option in UE.

2.3 Hardware, Structure, and Technical Challenges

Hardware and software

The VR experience was created on a Windows 11 PC with these specifications: Intel i9-11900KF CPU, 32 GB DDR4 RAM, 2x 1TB NVMe disks and a NVidia GeForce RTX 3090, with 24 GB VRAM as GPU. Since we aimed for a natural, close to photo-real look, we opted to use this high spec ’ed gaming PC (at the time of purchase in December 2021). The most important part of the PC is the graphics card, since the scene is very render heavy, and driving the VR headset is even more taxing than showing a scene on a regular PC screen. It's been challenging to reach a satisfying frame rate for the VR headset, since we push the graphic quality rather high. So, the limiting factor has been the speed of the GPU, not the other components of the PC. The software used are Unreal Engine 4.27.2, Houdini 19.x, Visual Studio 2022, Steam VR, GitHub Desktop. The VR headset we have used is the HTC VIVE Pro 2, which is a good, comfortable headset with decent headphones attached. It has a high resolution of 4896x2448 at 120HZ, one of the best VR headsets available. The screen door effect is also neglectable, and the pixel size is very good (small). In this project we found that the "sweet spot"—the position that the user sees the screen 100% clear in the HMD is indeed narrower on this headset than for instance the HTC VIVE Pro, which we have experience of from earlier projects. This means that it is even more important that the user gets the inter-pupillary distance (IPD) set correct and wears the headset correctly on the head. Else the image will be somewhat blurry. Also, because of the battle with reaching acceptable framerates, we found that we could not afford to run our scene with full resolution and ended up with using the Balanced (3264×1632, 90 Hz) setting. This is just above the HTC VIVE Pro resolution of 2880x1600. So, in retrospect we might have been better off with using the older headset, with a larger sweet spot and good enough resolution. VIVE Pro also comes with a version of VIVE Pro Eye, that has eye tracking which would allow us to use foveated rendering, and thus probably reached higher framerates - or better graphics in other ways. The VIVE Pro 2 has other benefits though, as the mentioned smaller screen pixels with less screen-door effect, and a little larger field of view with about 15˚ more horizontal, and about the same vertical.

Framerate and optimizing

We have used several optimizing techniques to improve the framerate. The meshes are mostly batch rendered. Houdini does this by default, batching together similar meshes from the procedural made scenario. Inside of Unreal we discovered that it probably would have been even better to have more manual control over what is batched to what, but that would of course mean more manual work. Unreals Occlusion Culling was tried but did not have a large effect since the batches from Houdini are quite large. The materials are another area we can improve. We have used pre-made assets from several vendors, and they all use their own material setup. Even assets from the same vendor often uses separate materials on similar looking models. For instance, we have a large set of different vegetation types, that all could use the same material with different textures (preferably from a set of texture atlases), but now they use their own materials. The cars are another example that should be using the same material, just with colour variations. This could have saved many draw-calls, which is what the GPU is overloaded with now, according to the Unreal Profiler. Unfortunately, we did not have time to go through and manually remake all the materials, but this is a strong recommendation for future projects – plan and fix the material of your models at the time you import them into your project. Then you can avoid a large backlog at the end. The current version reaches the framerate of around 120 FPS in the urban scenario and drops to 60-70 FPS in the green area. This is not ideal, since a steady 90 FPS is the standard on PC VR now.

Unreal Engine and project structure

The structure of the Unreal Project is straight forward - just one Level with both the scenarios placed some distance away from each other. This did not influence the performance, since you cannot see one from the other, thus Unreal culls out the one not in view and the GPU does not use additional resources. The advantage of having it this way was the ease of jumping from one to the other when editing and working with the scene. We made or own portals to jump between the scenes that the user is freely able to walk through at any moment. The portal itself is just translating the player between the two portal positions and using the direction the user walks into the portal. The portal rendering is a static cube-map texture, captured 1 second after the program starts. This way it always shows the current look of the scenes, even with quick iterations of editing the visuals. The material also has a waving quality to it, to make the portal more "magical" and not just a flat plane. Also, this hides that the cube-map is not updated in real-time when the game is running. The basis of the project and the movement system is largely written in C++, but Blueprints are used in the editor for some parts. For instance, the programming interface for the trackers are only available in Blueprints.

Movement and tracker experiences

In this project we wanted the walking experience to feel as close to real walking as possible. At the start, we discussed different means to reach this goal - using a treadmill that we have prior experience with, using an exercise bike, or using trackers; small devices attached to the user to detect the movement and direction of limbs. The use of regular game controllers and pushbuttons as the only means to move and turn, was quickly dismissed. When looking at pros and cons, we discarded the initial idea of using a manually driven treadmill, as we did in a pilot study (Litleskare et al., 2022), as this solution is limited to movements in one direction. Sharp turns would be problematic to convey, and we wanted the user to be able to move around freely. Also, a treadmill is large, heavy, and complicated to transport to different locations. A bike could have worked well with a sensor on the steering wheel to allow the user to decide where to go. But a bike is usually going rather fast, and we wanted the experience to be calmer, and not just seeing the nature fly by from the bike seat. We decided on using the HTC VIVE Tracker (3rd edition). These are rather small sensors that can be attach to the body of the user. They transmit their position and rotation in space in real-time to the PC. We decided to use three of these trackers; one attached to the waist of the user to sense the direction of the body, and one for each ankle to get the movement of the feet. This allows the user to walk and stop as they want and turn in any direction at any given moment. Because of the waist-sensor, the user walks in the direction of the upper body, while allowing free head-movement. This was important, since the experience is inviting the user to look around. We experimented with dynamic speed adjustment which would allow the user to walk faster or slower depending on the speed of movement of their feet, but this became problematic because people walk differently. Some lift their feet high, some low, some take long steps, some take short, some have quick steps, some slow. So, per now, we have a fixed speed that is triggered when the users move their feet above a specific threshold. This also links into the issue of cybersickness. If the speed of movement is not what the user expects, more people tend to get sick, but tests have shown that moving in a fixed tempo is acceptable for most people. One quirk may still arise as the trackers on the feet are read as movement forward with the direction given by the waist sensor. This will cause a person that stands still and mean to simply turn around in a set position to move forward in the virtual environment when they lift their feet to turn around. We have not found a robust method to solve this issue.

The last hurdle with using sensors as movement input is that the user can of course not actually walk around in real life. Our scenarios have several hundred square meters for the user to explore, and the cord of the headset, plus the free playable area is just a meter or two. The idea is to get the user to "walk in place, threading water" to move, and turn around themselves when wanting to change direction. With training this can become quite natural, but of course our users have only about 5 minutes in the experience total, so they have to figure out this mechanic very quickly. This was OK for many of our users, but it was unnatural for some.

Optional Movement methods

To be more inclusive, and to have an alternative to the ones not being comfortable walking upright, we implemented some optional methods to move and turn. This included siting in a rotating office chair and use the feet (when sitting) to turn and move. You could also use the ankle sensor(s) connected to your hand(s) and move the hands up and down to move forwards in the environment. Lastly, you can use the buttons on the VIVE hand-controllers, one to steer direction, the other to control movement. Any combinations of this can be used, so we can offer a solution for everyone, from standing participants to participants in a wheelchair.

2.4 List of hardware, software and online services used for the showcase

Software

- Adobe Substance Designer: Is a computer graphics application for creating textures developed by Adobe Inc. (2023). Adobe Substance Designer. Link to source
- Adobe Substance Painter: Is a computer graphics application for creating textures developed by Adobe Inc. (2023). Adobe Substance Painter. Link to source
- Autodesk Maya: Is a 3D computer graphics application developed by Autodesk, INC. (2019). Maya. Link to source
- GitHub Desktop: Is an open-source application that allows users to interact with the GitHub platform in a graphical interface. GitHub. (2023). Link to source
- GitHub: Is a web-based hosting service for version control using git. GitHub. (2023). Link to source
- MapBox: Is a provider of custom online maps for websites and applications. Mapbox (2023). Link to source
- OpenStreetMap (OSM): Is a free, open geographic database updated and maintained by a community of volunteers via open collaboration. OpenStreetMap (2023). Link to source
- SideFX Houdini: Is a 3D computer graphics application developed by SideFX. SideFX. (2023). Houdini. Link to source
- Steam VR: Is a Virtual Reality Platform developed by Valve (2023). Link to source
- Unreal Engine: Is a game engine developed by Epic Games. Epic Games. (2023). Unreal Engine. Link to source
- Visual Studio 2022: Is software suite for writing computer programs developed by Microsoft (2023). Link to source

Hardware used for the final VR showcase

- HTC VIVE Pro 2: a VR system produced by HTC Corporation (Xindian, New Taipei, Taiwan), consisting of a HMD, various accessories (including two hand-held controllers and two external base stations), and a VR software.
- HTC Vive Tracker (3rd edition): an HTC accessory consisting in motion tracking devices that can be attached to a person's limbs, which are tracked via the base stations and allow to reproduce movements in the virtual world.
- Windows 11 PC: Intel i9-11900KF CPU, 32 GB DDR4 RAM, 2x 1TB NVMe disks and a NVidia GeForce RTX 3090, with 24 GB VRAM as GPU

Hardware for preliminary tests

- Insta360 One X2 camera: 360° camera that can generate 360° photos and videos.
- iPad Pro (11-inch) (2nd generation) with LIDAR

BOX 3. LIST OF COMPONENTS OF THE VR EXPERIENTIAL SHOWCASE, AS IT WILL BE DISPLAYED IN THE CULTIVATING CITIES

Hardware components:

- Komplett i261 Epic Gaming PC, with keyboard and mouse
- HTC VIVE PRO 2 Full Kit (HMD, hand-held controllers, base stations, and connecting cables)
- HTC Vive Tracker 3.0 (1 for waist and 2 for ankles), with belt and strap bundle

Additional components:

- Floor-mat (130x130 cm)
- Light tripods to support the base stations (2)
- Microphone stand to hold HMD cable
- Extra HTC PU Leather Face Cushion for VIVE PRO to change in between participants
- Two roll-up banners for promotional purposes

Devices to perform assessments:

- Table stopwatch Hanhart Prisma 200 to measure duration of exposure
- Tablet with link to online survey

Transportation:

- Computer’s flight case with wheel
- Two sport bags with wheels

3. The Kick-off events

Following the digital launch in June 2022, the Showcase was exhibited in September 2022 in a series of kick-off events in three Norwegian cities (Hamar, Elverum, and Drammen). The events were organized as part of the annual Forskningsdagene ("Days of research"), a national open-science event during which research institutions organize events to involve citizens in various scientific topics. The events took place at the University Campuses of the respective cities which are normally populated by university students, but are also lively meeting places for local citizens who gather there to visit the library, mingle at the cafeteria, use the sport facilities, etc. For each event, a stand containing the Showcase installation was open to the public between 11:00 and 17:00. All local citizens of age 16 or older were invited to participate. The events were advertised through the webpages of the universities, local news outlets, the Forskningsdagene event, and the GoGreenRoutes project. The events were covered by the Universities' as well as the GoGreenRoutes' communication department, who reported the events on their respective social media channels.

BOX 4. THE KICK-OFF EVENTS

After its online launch this summer, the VR Experiential Showcase was presented to the public during a series of kick-off arrangements in three Norwegian cities, under the umbrella of the Norwegian national event *Forskningsdagene* ("Days of research"):

- **26th September 2022, Hamar**
- **27th September 2022, Elverum**
- **30th September 2022, Drammen**

See the interview with Prof. Calogiuri, coordinator of task 6.4, at the kick-off event in Elverum.

Note: Prof. Calogiuri is Professor of Health Sciences at the Centre of Health and Technology, University of South-Eastern Norway. She also olds an Adjunct Professor position at the Inland Norway University of Applied Sciences, through which she contributes to GoGreenRoutes.

3.1 Outcomes of the events

It is fair to state that the events were a success, as many citizens lined-up to try the Showcase and gave positive feedback, although some also provided some useful constructive feedback that will help use further improving the installation. A large part of the participants were people passing by, including university students, campus employees, or other visiting citizens. Some participants came specifically to experience the VR installation attracted by the advertisements that circulated on the preceding days. In total, 83 people engaged with the VR experience, of whom 43 were women, 39 men, and 1 non-binary (age range 18 - 73 years old). Most of the participants tried the walk-in-place trackers, though five participants preferred to undergo the experience whilst sitting on a swivel chair. In average, the participants who tried the Showcase immersed themselves in the virtual world for about 4-minutes, with a minimum of 41 seconds and maximum of 10 minutes.

Following provision of informed written consent, a brief survey was administered among the participants to assess whether the Showcase could elicit increased feelings of nature connectedness, as well as other perceptions and beliefs relative to the users' experience. Based on this survey, we could estimate that, in average, the participants' self-reported levels of nature connectedness increased from before-to-after the experience, especially among those who reported a lower affinity for nature before trying the Showcase. The large majority of participants reported high levels of enjoyment as well as fairly high feelings of presence in the virtual world. However, some challenges emerged with respect to cyber-sickness, as many reported to have experienced dizziness while using the Showcase. When asked to write one word that summarized their experience with the Showcase, most participants described the experience as "Exciting" or "Fun", but many also depicted it as "Calming" or "Nice". Some praised the technology as "Realistic", though some appeared less impressed, reporting how the virtual world seemed "Artificial", or mentioning other technology-related challenges such as the "Unnatural walking" or the feeling of "Dizziness".

Figure 7. Citizens engaging with the VR Experiential Showcase at the chick-off events in Elverum and Drammen

Credits: Giovanna Calogiuri

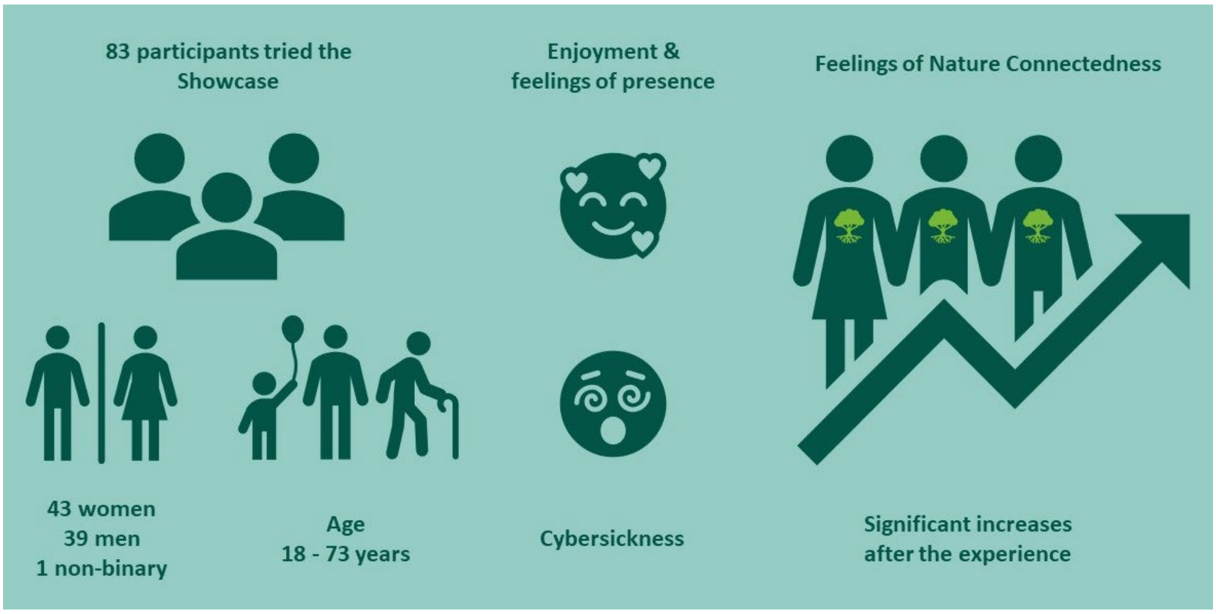

Figure 8. Outline of the outcomes of the kick-off events of the VR Experiential Showcase in three Norwegian cities.

Credits: Giovanna Calogiuri

Figure 9. A word-cloud summarizing the experience of the participants who engaged with the VR Experiential Showcase during the kick-off events in Norway.

Credits: Giovanna Calogiuri

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Høgskolen i Innlandet

Denne rapporten ble utviklet som en del av forskningsprosjektet «GoGreenRoutes». Nærmere bestemt, rapporten beskriver aktiviteten tilknyttet oppgave 6.4 (arbeidspakke 6), som har som mål å designe og lage en Virtual Reality (VR) installasjon for å øke bevisstheten om miljøutfordringene knyttet til urbanisering, formidle fordelene ved aktivitet i naturen, og fremkalle følelser av tilknytning til lokale steder. Installasjonen vil bli vist i alle byene som inngår i GoGreenRoutes. I denne rapporten gir vi først en overordnet begrunnelse for arbeidet, med en kort oversikt over generelle begreper knyttet til VR-teknologi og teknologiens potensial for å formidle og fremme naturopplevelser. Vi beskriver deretter prosedyrene og instrumentene som ble brukt for å utvikle installasjonen, samt maskinvaren som ble brukt for å levere dette. Til slutt presenteres en oppsummering av tre "kick-off events" som ble gjennomført i tre norske byer med hensikt å lansere installasjonen, samt å teste den i forbindelse med et offentlige arrangement.