Bacheloroppgave

IBE600 IT og digitalisering

Implementation of Augmented Reality to increase participation from young children in the hiking program Stikk Ut!

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Abstract

In this bachelor thesis, a web-based Augmented Reality application is proposed to motivate children to engage in the hiking activities offered by Stikk ut! The goal is to deliver a proof of concept in which AR enhances the experience of walking in nature through a game that makes hiking more appealing for children.

The application will provide an augmented reality hiking experience that will combine virtual and physical aspects by using geolocation data with virtual overlay. Its theme will aim to foster care for the natural environment, encouraging children to become environmentally conscious and responsible.

This thesis work is divided into seven chapters. Since augmented reality is the core feature of the application, understanding what this technology is, and how it works was considered an important chapter in the project. After delving deeply into what AR is, it was easier to make judgments on which AR framework, tracking methods, and devices were most suited for the application's development.

Furthermore, during the development process, the concepts of agile methodology were employed, providing a theoretical foundation for how to execute each phase of the development in an effective manner.

The application evolved from a sketched idea to a functional product ready to be tested. User testing and feedback provided important insights on whether a solution like this would be feasible and revealed which features needed debugging and improvement. The project concludes with recommendations linked to the results obtained from the project as well as some important aspects that were not included in this work due to limited time.

Sammendrag

I denne bacheloroppgaven foreslås en web-basert Augmented Reality applikasjon for å motivere barn til å delta i tur programmet Stikk ut! Målet er å levere et «proof of concept» der AR forbedrer opplevelsen av å gå i naturen gjennom et spill som gjør fotturer mer attraktivt for barn.

Applikasjonen vil gi en Augmented Reality turopplevelse som vil kombinere virtuelle og fysiske aspekter ved å bruke geolokaliseringsdata samt virtuelt overlegg. Temaet vil ta sikte på å fremme omsorg for det naturlige miljøet, og oppmuntre barn til å bli miljøbevisste og ansvarlige.

Denne oppgaven er delt inn i syv kapitler. Siden AR er den kjernefunksjonen i applikasjonen, relevant teori om denne teknologien ble ansett som en viktig del av prosjektet. Etter å ha fordypet seg i hva AR er, var det enklere å ta vurderinger på hvilket AR-rammeverk, sporingsmetoder og enheter som var best egnet for applikasjonens utvikling.

I tillegg, ble prinsippene for Agile metodikk brukt under utviklingsprosessen, dette ga et teoretisk grunnlag for hvordan man kan utføre hvert trinn i utviklingen av prosjektet på en effektiv måte.

Applikasjonen utviklet seg fra en skissert idé til et funksjonelt produkt klar til å bli testet. Brukertesting og tilbakemeldinger ga viktig innsikt i hvorvidt en løsning som denne ville være gjennomførbar og avslørte hvilke funksjoner som trengte «debugging» og forbedring. Prosjektet avsluttes med anbefalinger knyttet til resultatene innhentet fra prosjektet samt noen viktige aspekter som ikke var med i dette arbeidet på grunn av begrenset tid.

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1.0 Introduction

"Stikk ut!" is a hiking program created in Molde which has expanded to different municipalities of Nordmøre og Romsdal. This program offers hiking guides that include the tour location, difficulty level, and a brief description of it including distance and height. Each hiking route has an identification number and is signposted to its final destination. Hikers can record their trip in a guest book that can be found in a post box located along all trails or by using Stikk ut!'s app. (Friluftsrådet Nordmøre og Romsdal, 2020).

"Stikk ut!" is an initiative from the Nordmøre og Romsdal Outdoor and Recreation Council (Friluftsrådet Møre og Romsdal) to get more people out for a walk. It operates in collaboration with all members of the municipality in Nordmøre og Romsdal county and volunteers. This offer is one of the most successful hiking programs with the largest number of participants in Norway (Elshaug, n.d.). Despite this, it also experiences a number of challenges that pose a threat. Some of these challenges identified during the workshops and meetings held as part of the strategic plan of the Nordmøre og Romsdal Outdoor and Recreation Council in 2020, are: reduced popularity among the society, the success is a trend of fashion (temporary), the participants tend to lose interest in hiking, the little self-effort of the municipality, and the existence of other hiking apps. Thus, one of the purposes established in the strategy of Stikk ut! is to stimulate outdoor activities for all in a sustainable way.

1.1 Problem statement

Tibe Molde is a communication agency that has been operating since 1986. It offers services such as graphic design, campaign implementation, web design, and web development, among others. This agency is in charge of the structure of the Stikk ut! database and website, as well as the design of the physical route maps.

As a collaboration partner and supplier of Stikk ut! Tibe has given me the task of finding a way in which digital tools can be used to encourage young people to be active outdoors and participate more in this hiking program.

This thesis will address one of the challenges that "Stikk ut!" faces by developing a demo application to achieve a minimum viable product that promotes physical activity among children between ages 7-10 and thus increase their participation in this program. A minimal viable product (MVP) is a product with only enough functionality to bring in early adopters and verify a product concept early in the development cycle (Minimum Viable Product (MVP), 2022). Testing an idea with users allows to receive quick feedback about the product. Feedback not only reveals what are the features that need improvement, but also allows to verify if an application will appeal to customers before putting effort and expense in a fully developed product (McDonald, 2023).

The approach focuses on the use of augmented reality to enhance the hiking experience in some of the Stikk ut! trails. Taking advantage of the connectivity and interest in mobile devices, it is intended to digitalize the treasure hunt game, using augmented reality in an application that integrates the activity of walking with a digital game.

2.0 Augmented Reality

Augmented reality is a very promising emerging technology in which many companies are investing large capital. Much of this is due to the hit game Pokemon Go, which reached 500,000 downloads in just 43 days, and not only raked in huge profits but also proved that technology is capable of making us more active in a very innovative way (TEDx Talks, 2017). Augmented reality provides access to information that would otherwise be imperceptible to the human senses. This information has the potential to improve our interactions with the real world, facilitating many tasks. For this very reason, the implementation of AR is increasingly common in different domains, including military, manufacturing, education, health, entertainment, and navigation among others. An example of AR in commerce is Ikea, which has opted for an application that allows furnishing interiors with its virtual products in a real space. When it comes to education, this technology offers new teaching possibilities. Students have the opportunity to visualize abstract concepts and witness phenomena that are not possible to witness in the real world (Dutta, n.d.). And when it comes to health, the accuracy required by certain surgeries can be visually guided using augmented reality (Mekni, M., & Lemieux, A., 2014).

Understanding what augmented reality is, and what it entails is essential for designing an application based on this technology. The definition and fundamental components of this technology are briefly described in the following sections.

2.1 Definition

In 1992 Tom Caudell and David Mizzell found a way to make Boeing´s manufacturing process easier with a software that overlayed the positions of cables in the building process through a head mounted display. It was then that they coined the name Augmented Reality (Kipper & Rampolla, 2012).

To clarify what this technology actually entails, the following definitions have been used.

Azuma (1997) states that augmented reality is a variation of virtual reality. The former enables the user to see the actual environment while virtual items are overlaid or composited on top of it. Whereas the latter immerses the user completely in a synthetic environment. Augmented reality supplements reality by combining real and virtual objects in 3D, giving the illusion that they coexist in the same space.

According to Kipper and Rampolla (2012) Augmented reality (AR) refers to the process of overlaying digital or computer-generated information, such as photos, music, video, touch, or haptic sensations, over a real-time environment. Up until now, the main and most common application of AR is for visual enhancement. However, all five senses can be improved by augmented reality.

Another definition given by Furht (2011) says that AR is a real-time view of a physical real-world environment enhanced with virtual computer-generated information to it in a direct or indirect manner. This technology is interactive, and 3D registered in real-time. AR enables us to enhance our perception of the real world by blending physical and virtual items along with cues.

Summing up, augmented reality is any system that enhances our perception capabilities by adding digital elements to the real world. The definitions coincide in that the key aspects of augmented reality are that it combines the real and the virtual worlds, is interactive in real-time, and includes precise 3D registration of virtual and real objects.

2.2 Augmented Reality Technologies

Augmented reality systems are complex, they require certain core components in order for them to work. Hardware and software are both necessary, more specifically a display, tracking system, and interactivity (Wen, 2023).

2.2.1 Display

The display is the element that captures the images of reality that users are seeing. Likewise, it is in charge of projecting the mixture of real images with synthesized images.

According to Furht (2011) the three main displays for augmented reality are head-mounted displays (HMD), handheld displays, and spatial displays.

2.2.1.1 Head-mounted display (HMD)

A head-mounted display as its name indicates, is a device worn on the head that overlays images of the real and virtual environments on the user's view of the world. It can be video-see-through or optical-see-through, with either a monocular or binocular display optic. Video-see-through systems require two cameras to provide both the "real part" of the augmented scene and the virtual objects, while optical-see-through employs a half-silver mirror technology to allow views of the physical world to pass through the lens and graphically overlay information (Carmigniani et al., 2011).

2.2.1.2 Handheld displays

These kinds of displays are small computing devices with screens that can be held in the user's hands. They use sensors such as digital compasses and GPS units, fiducial marker systems, and/or computer vision approaches. There are three major kinds of commercially accessible handheld displays being utilized for augmented reality systems: smartphones, PDAs, and Tablet PCs. Smartphones are portable and widely available, with powerful CPUs, cameras, accelerometers, GPS, and solid-state compass (Furht, 2011).

2.2.1.3 Spatial displays

Video projectors, optical components, holograms, radio frequency tags, and other tracking technologies are used in spatial displays to show graphical information directly onto real objects without needing the user to wear or carry the display (Furht, 2011). This allows for user collaboration, hence raising interest in augmented reality systems.

2.2.2 AR tracking

Tracking technology provides the necessary data for the computer to determine where and when to activate the virtual objects. AR tracking techniques can be classified as sensor-based tracking and vision-based tracking. Sensor-actuated tracking is subdivided into optical, magnetic, auditory, and inertial tracking (Ashwini et al., 2020). Marker-based and markerless tracking are two types of vision-triggered tracking (Zhou et al., 2008, as cited in, Rabbi & Ullah, 2013). Due to its relevance to this project GPS tracking has been added to this classification as a sensor-based subcategory. This classification is illustrated in the following diagram.

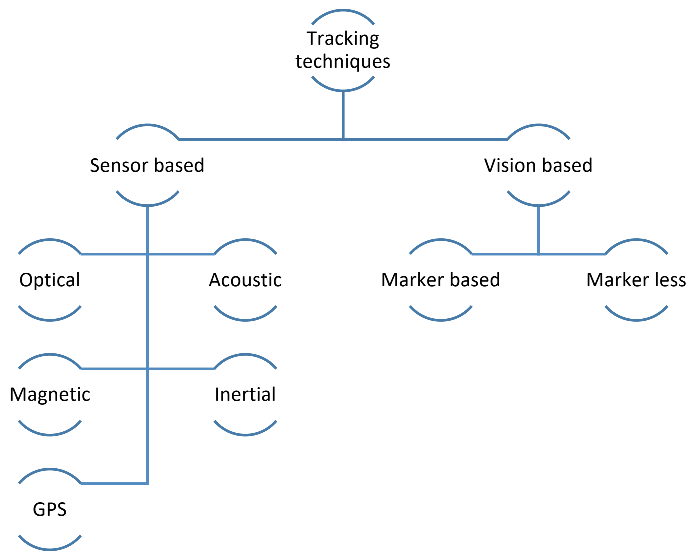

Figure 1 Tracking techniques classification. Based on classification from Rabbi and Ullah (2013)

2.2.2.1 Sensor based tracking.

This tracking method relies on sensors to track the position of the camera. The most common sensors used for AR tracking are enlisted as follows.

Optical sensors use video cameras placed in different angles to view the target. In order to perform 3D tracking, two video cameras must be used. The position and angle of the camera are obtained using epipolar geometry (Fig. 2) (Sehatullah, 2011, as cited in, Rabbi & Ullah, 2013). Results are accurate and robust when implemented in a controlled environment, but the process is expensive and slow due to heavy computation.

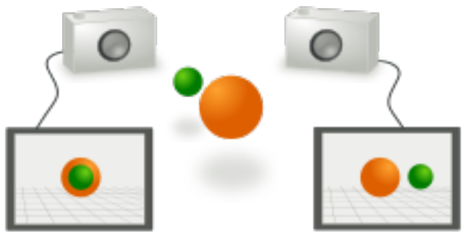

Figure 2 "Typical use case for epipolar geometry: Two cameras take a picture of the same scene from different points of view. The epipolar geometry then describes the relation between the two resulting views. " (Wikipedia contributors, 2022) https://en.wikipedia.org/wiki/Epipolar_geometry

Magnetic sensors create magnetic fields and uses the fluctuations from these fields to measure the position and orientation of receivers in relation to the source (Ashwini et al., 2020). Although this tracking method is cheaper than the optical one, it is less accurate. In addition, magnetic tracking sensors have instability, accuracy diminishes with distance, and are susceptible to electromagnetic noise.

Acoustic tracking is performed with ultrasound emitters worn by the user, and sensors placed around the environment. The time it takes for sound to reach the sensors is used to calculate the user's position and orientation (Sehatullah, 2011, as cited in, Rabbi & Ullah, 2013). Due to the speed of sound, acoustic tracking systems are slower than other sensors. In addition, the speed of sound in the air might fluctuate if there are changes in temperature or humidity in the surroundings, affecting the tracking system's performance.

Inertial tracking converses either a particular axis of rotation (mechanical gyroscope) or a position (accelerometer). The mechanical gyroscope system is based on the idea of angular momentum conservation, and the rotating encoder angles can be used to calculate the target's orientation (Rabbi & Ullah, 2013). The accelerometer is a device that measures an object's linear acceleration, and it does not involve any other peripheral reference for its functioning. However, any small shift in the axis of rotation or the position may interfere with the performance of this tracking method.

GPS stands for Global Positioning System. It is a worldwide navigation system that locates specific points. GPS tracking devices communicate with the Global Navigation Satellite System (GNSS) through radio transmissions to gather data on location and direction (Lindahl, 2022). A GPS-enabled mobile device gets continual signals from the navigation satellites orbiting the Earth. It then triangulates its position using the time it takes the signals to reach the receiver as well as the angles at which the signals arrive (Mapscaping, 2023). The advantage of GPS trackers is that this technology is now integrated into almost all smartphones, allowing a large number of people to access it. One downside of this tracking system is that its performance is heavily reliant on the accuracy of the satellite signals. Although modern satellites are very accurate, there is no warranty for absolute precision. Entering an area with a poor signal or severe interference could impair the accuracy of a GPS tracker.

2.2.2.2 Vision based tracking.

According to Zhou et al. (2008), vision-based tracking techniques use image processing methods to determine the camera pose in relation to the objects in the real world. This tracking method can be done using fiducial markers (Fig. 3) in prepared environments (Maker-based) or by recognizing natural cues of real elements, such as gestures or face tracking (Markerless).

Marker based tracking identifies optical square markers in the camera image and estimates their relative position to the camera. A square marker is a predefined black square with a white border. The ID of the marker is stored within the square. To encode the ID, strategies such as template matching or encoding as a binary number can be used. Once the image is captured, it is converted to grayscale in order to speed up the image processing algorithm, edge detection, and registration. The camera image and virtual object are layered by using the camera image as the background of a display (real world) and the position of the marker. When the marker or the camera moves, the augmentation remains on the marker (in 3D space). Because the marker tracking pipeline is computationally cheap, all real-time interactions with virtual objects remain intact (Cukovic & Baizid, 2015). Some disadvantages of using markers are problems with recognition such as occlusion, poor illumination, and false positives.

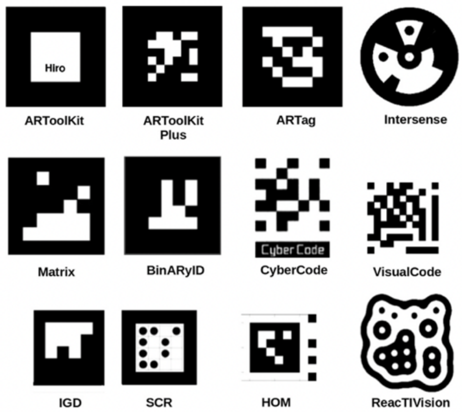

Figure 3 Examples of fiducial markers (Garrido-Jurado et al., 2014) "A fiducial marker is an object placed in the field of view of an imaging system that appears in the image produced, for use as a point of reference or a measure." (Wikipedia contributors. 2023a) https://en.wikipedia.org/wiki/Fiducial_marker

Markerless tracking does not rely on the usage of typical artificial markers that must be placed in the world in order for the system to determine their location and orientation (Teichrieb et al., 2007). In order to render virtual objects this technique uses any part of the real environment as a marker to perform tracking.

One technique used in vision-based markerless tracking is known as Structure from Motion (SfM). SfM based systems are capable of continually monitoring the camera's movements in unknown scenes. Real-time SfM can provide more information about the entire scene and data to improve tracking with features such as occlusion of virtual objects by real ones and physical interaction between them.

Another markerless approach is a learning-based descriptor in simultaneous localization and mapping (SLAM) (Aulinas et al., 2008). In robotics, SLAM is founded on the premise that a mobile robot can estimate a representation of the environment while mapping and localizing at the same time. This technique is performed using sophisticated sequential Bayesian inference algorithms and sensors such as laser rangefinders and sonar (Teichrieb et al., 2007). Its disadvantage is that it may be computationally costly (Takleh et al., 2018), making the mapping of large areas challenging.

2.2.3 Interaction

Interaction involves techniques that enable the users to interface in an intuitive way with the AR environment, that is, both virtual and real contents. According to Furht (2011), there are four input methods for AR interaction: tangible AR interfaces, collaborative AR interfaces, hybrid AR interfaces, and multimodal interfaces.

2.2.3.1 Tangible user interface

This method merges the real world and the virtual world by giving a tangible feel to the virtual elements, hence making them appear more real. Adding haptic feedback gives a sense of physically interacting with the virtual data, enhancing the user experience. An example of this way of interaction is adding gesture-based commands such as pinching to zoom in or out, hitting an item to make it disappear, or flicking away objects to send them far.

2.2.3.2 Collaborative user interface

It consists of using a set of multiple displays to support remote sharing and interaction or co-located activities. Co-located sharing enhances physical collaborative workspace through the use of 3D interfaces. For instance, in a remote conference, participants can see each other sitting at a table and pick up on the same spatial cues as in a face-to-face cooperation. AR can easily combine numerous devices with various locations to improve teleconferences via remote sharing. The main goal is to enhance the face-to-face collaboration experience by giving a sense virtually co-located (Lukosch et al., 2015).

2.2.3.3 Hybrid AR interfaces

With this method, the interaction is achieved by combining different interfaces that at the same time have the ability to interact through different devices. Such interfaces provide flexibility in situations where the type of interaction display or device is unknown. An example of a hybrid interface is the MagicBook, which is a normal book with images and text. These images also function as markers that activate 3D virtual objects overlaid on the book when scanned through an AR display. Users can choose an AR scene from the book and immerse themselves in virtual reality. Once immersed, they are networked together, see the virtual images from their own point of view and collaboratively explore the virtual world. (Billinghurst et al., 2001).

2.2.3.4 Multimodal interfaces

In a multimodal interface, users are able to interact with real objects using natural language and behaviors, such as speech and gestures (Kipper & Rampolla, 2012). Users gain from the ability to combine several modalities and select the best appropriate input for a specific task or circumstance. Furht (2011) affirms that due to its robust, efficient, expressive, and highly mobile nature, this type of interface is being developed and is projected to be a preferred method of interaction for future augmented reality applications.

2.3 Challenges of AR

Despite the different advances, continuous development, and interest in augmented reality, certain limitations and challenges have yet to be overcome. Up until now, the mobility of this technology is focused on the usage of smartphones. Other display devices, such as head-mounted devices are neither fashionably acceptable nor economically affordable. Furthermore, see-through displays, are still not suitable for outdoor use due to their low resolution and brightness (Rabbi & Ullah, 2013). In addition, depth perception must be improved so that virtual objects adapt naturally to the context in which they are deployed. Augmented reality applications also must adhere to specific criteria in order not to overwhelm the consumer with information, they should be subtle and maintain the natural cues of the real world. Another issue is that users may concentrate on the part of the real world that is showed on the AR display, forgetting the rest of their surroundings, which can lead to accidents and physical harm. Finally, social approval is quite crucial. Even though AR offers many benefits, people's acceptance is not always favorable. Furht (2011) says that the main problem with societal acceptability is the disruption caused by mobile devices in public spaces and during conversations. Among other factors that might influence social acceptance are portability, appearance, and privacy. A technology with the capability of overlaying digital texture over a user's environment, and collecting data makes its use questionable when it comes to how private information is handled.

2.4 AR applications

The application developed in this project will be a game that includes location-based AR, and its purpose will be to enhance outdoor physical activity. Three applications with comparable features are mentioned further down. This will provide insight into what is available on the market as well as the structure of existing augmented reality apps.

Zombies, Run! is a premium app that blends a running game with an audio narrative as its major feature. The player is involved in a scenario in which the tasks are collecting supplies to grow a post-apocalypse community while escaping from zombies. As zombies approach the player must speed up. With every run, vital supplies are collected, and all achievements can be shared with friends (App Store, 2012). This AR app records time, speed, distance, calories burned, etc. Its core feature is interactivity since it makes people run the whole distance instead of giving up after 15 minutes (Titov, 2020). This application shows clearly how augmented reality can enhance not only vision but also other human senses, in this case, sound.

Pokémon Go is an app that uses location tracking and mapping technology to create augmented reality combining fictional characters with the real world. Pokémon characters appear on the game map as users walk in the real world. As soon as users get close enough, Pokémon will appear on the device's screen and users can catch them by throwing Poké Balls at them. When it comes to interface, this app stands out for its attention to detail. Its map is an anime version of Google Maps, that substitutes real-world street names and landmarks for Pokémon-themed names. This application immediately obtained a solid market position due to its novelty and the fact that the game is nostalgic for many players, as Pokémon was a phenomenon in the late 1990s and early 2000s. This was also the first time an augmented reality game became popular (McGarrigle, 2019).

Ingress is an augmented reality, multiplayer location-based game created by Niantic Labs. It was originally exclusive for Android devices but became cross-platform in 2014 (Ingress | Ingress Wiki | Fandom, n.d.).

The game uses GPS along with geographical features supplied by OpenStreetMap to locate and interact with "portals" in the player's real-world location (Wikipedia contributors, 2023b).

The mechanic of the game is the control of portals. Portals are real-world places. Interaction is done when players physically visit a portal and view it in the Ingress application through a mobile device. Portals are often prominent man-made sites such as public art, memorials, historic buildings, and so forth (Ingress Overview | Fev Games, 2023).

3.0 The Monster hunt application demo

The treasure hunt is a well-known game in which the participants are tasked to find a treasure by overcoming a list of challenges or solving a set of riddles. A riddle is a statement, question, or phrase with a hidden or double meaning that is presented as a problem to be solved (Wikipedia contributors, 2023c).

This project is intended to digitalize the treasure hunt game and adapt it to the context of hiking in nature. Since both Stikk ut! and Tibe are concerned about the environment, the theme for the application will be related to caring for the environment. For this version of the treasure hunt, the target to find is not a treasure but a monster who likes to pollute the environment and must be captured.

The general idea for this solution is represented in a Use Case Diagram. Also referred as behavior diagram, an UML is a high-level diagram used to describe a set of actions that a system can perform in collaboration with one or more external users of the system (Fakhroutdinov, n.d.). In Fig. 4 the rectangle in the diagram represents the system and the persons outside of it represent actors, which are the organizations or actual people that will interact with the system in order to achieve a goal. The round elements inside the rectangle are representing actions that accomplish some sort of task within the system. Each action is known as a use case, and they are placed in a logical order. The lines and arrows represent relationships between the elements in the diagram. The user has direct interactions with the system (represented with a solid line) by starting the application through login, scanning the AR models, and updating its profile. Stick ut! interacts directly with the system by providing it with the necessary data about a given tour and a user profile (represented with red dashed lines). The green dashed lines indicate actions performed within the system which have no direct interaction with the actors.

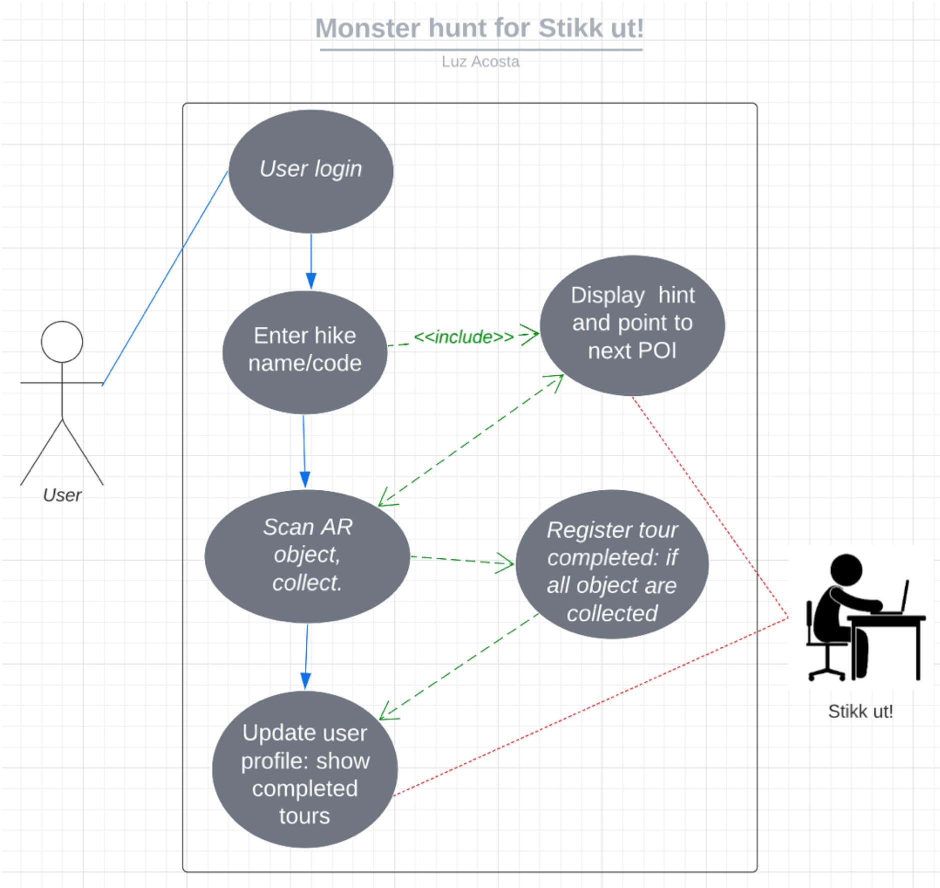

Figure 4 UML diagram for the Treasure hunt application

In the Monster hunt application, after the player logs in and enters a tour name, a set of clues or riddles is provided and must be solved in order to find the path to the monster. This process iterates until all the riddles are solved, then the tour can be completed and registered on the user profile. Completed trails can be collected on the user profile and this way users can compare or share their activity with other users. Having a profile is also thought of as a possibility to arrange events or competitions that include actual prizes, hence reinforcing motivation for hiking.

4.0 Tools and frameworks

Different tools and frameworks were necessary to keep good visibility and facilitate the development of this application. Project management, augmented reality, and programming were performed with the tools and frameworks described in the following sections.

4.1 Kanban

Initially, Scrum was considered as the agile framework to develop this application. This would allow to achieve small goals each week, such goals are known as Sprints. However, because the framework for implementing AR was not yet defined, the Sprints became difficult to complete. Therefore, the framework was changed to Kanban.

Kanban is an Agile Software Development Methodology that enables the visualization of an existing workflow in terms of steps. "Kanban is about visualizing work, limiting work in progress, and maximizing efficiency" (Rehkopf, n.d.). The cards used in a Kanban board allow to keep track of what is been done and what needs to be done. A visual concept like this facilitates the completion of tasks more efficiently since a single task is being performed at once. Kanban enables transparency and flexibility, which makes the development process smoother.

4.1.1 Trello

Trello is a free project management tool that allows to easily configurate a Kanban board. The board for this project included a backlog list where the Kanban cards where added. Each card representing a single task could be moved to different stages “to do”, “doing”, “testing” and “done”. Small descriptions and notes to different tasks could be added as necessary, facilitating the work progress in an orderly way.

4.2 Replit

Replit is an integrated development environment (IDE) with all the tools needed to develop, test, and host an application. This platform supports various programming languages and includes collaborative coding.
An IDE with several integrated features in one place makes it possible to edit code and host a web page instantly. This simplified the development process, and the main features of the application could be prioritized. For instance, it was possible to test how accurately 3D models were rendered in different outdoor locations simply by copying the Repl Webview URL and pasting it onto the browser in a mobile device to launch the application.

4.3 AR framework

In the past years advances in technology have enabled high-level connectivity. Sophisticated mobile devices and fifth-generation cellular networks allowed augmented reality to become well-adapted to mobile devices. Because of these possibilities, augmented reality has gained popularity with applications such as Snapchat or Pokemon Go. Along with this popularity, the variety of augmented reality frameworks increased as well, giving developers plenty of options to create AR content.

Two frameworks for augmented reality were tested and analyzed, with the aim of choosing the one that best suits the characteristics and requirements of this application.

4.3.1 Lens Studio

According to its official website Lens Studio (2023) is a desktop application that allows designing and building augmented reality experiences that can be deployed on the mobile application Snapchat. This framework has a cross-platform distribution on iOs and Android. Programming is performed in both visual and traditional ways through a Script Graph Editor and code editor using JavaScript. It has multiple tracking options and features like segmentation and landmarker tracking. The former refers to the ability to segment a portion of the camera and replace it with an image or an effect, and the latter refers to the feature of tracking a physical location landmark, allowing to create a three-dimensional experience closely tracked to a location's architecture, this kind of tracking can be achieved with the use of a LiDAR-enabled mobile phone. Lastly, one of its most powerful features is the use of machine learning to attach images to custom-detected objects or understand the content of a scene.

4.3.2 AR.js

AR.js is a free and open-source, JavaScript-based library, which makes it possible to develop augmented reality content on the web. The features included in this library are image tracking, location-based AR, and marker tracking. In addition, one of its key points is that it includes cross-browser compatibility. That is, it works on both Android and iOS mobile devices that support Web Graphics Library (WebGL) and Web Real-Time Communication (webRTC). Its performance is up to 60 frames per second. Since this solution is purely web-based, it does not require any installation, making it possible to obtain AR content from a single HTML file (AR.js Documentation, n.d.).

Two important frameworks used by Ar.js are described as follows:

1. A-Frame is a framework that provides a markup language to build 3D experiences using familiar web developer tools (Building up a Basic Demo With A-Frame - Game Development | MDN, 2023).

   Created originally by Mozilla it is based on top of HTML, its core is a powerful entity-component framework that provides a declarative and extensible structure to three.js (Introduction – A-Frame, n.d.). It supports most of VR headsets and its goal is to achieve fully immersive interactive experiences, with the positional tracking and controllers.
   The fact that is based on HTML makes A-Frame very accessible, its entity component structure provides versatility and access to other possibilities such JavaSscript, DOM APIs, three.js, WebVR, and WebGL.

2. Three.js is a Web-Graphic-Library engine based in JavaScript that makes possible to run GPU-powered engines and graphic applications from a browser (Three Js - MDN Web Docs Glossary: Definitions of Web-related Terms | MDN, 2023). Using this framework developers can create complex animations that include light effects, textures, materials, and shadows can be rendered on HTML.

4.4 Framework comparison and choice

After trying both frameworks, a comparison was made according to the possibilities and requirements involved in the development of the Treasure hunt demo for Stikk ut!

Both tools can be implemented on Android and iOS. Lens Studio offers visual development and is the official platform for Snapchat. Among its most outstanding features is the use of machine learning and landmarker tracking, the former enables the detection of gestures, and the latter to generate location-based content. Although the application already exists and all what is needed is the creation of a lens with some interactions to achieve a treasure hunt like game, for users it is necessary to install Snapchat and create an account to use the lens. This can represent both an advantage as it is a well-established platform in the market, and a disadvantage depending on the users to whom it is directed, and the costs that this can imply for commercial use. In addition, the location-based content is limited to the recognition of previously mapped structures rather than a coordinate system, limiting its use in places where there are no well-defined structures such as natural landscapes. Despite using JavaScript and including a visual interface for programming, it gives the impression of requiring additional knowledge of graphic design and delving deeper into understanding the components of this program which can result challenging for newbies on the subject.

On the other hand, Ar.js makes possible to develop Augmented Reality directly on the web as originally planned, all what users need to experience AR, is to visit a website. This lightweight solution provides simplicity and flexibility for web developers, yet a wide range of possibilities. With A-frame entity components and the ability to use most web development tools like JQuery, DOM, React, etc. It lends itself to creating a myriad of projects, from a tourist guide to more complex games. No installation is required to use this framework, since all the tools needed can be imported through scripts inserted on HTML. It´s location-based feature uses Spherical Mercator which projects the earth onto a flat surface, enabling the use of latitude and longitude. This means that location-based content can be rendered anywhere, since the entities are GPS trackable.

Some of the disadvantages of using this platform are that Location-based does not work correctly on Firefox, due to the inability to obtain absolute orientation. Chrome might have problems on detecting the right camera on devices with multiple cameras. The mobile devices must have GPS sensors in order to use the location-based feature. Lastly the users must activate their GPS sensors and camera access on their browsers (AR.js Documentation, n.d.).

The comparison shows, that the AR.js framework adheres to the characteristics of the original idea of the application. These characteristics are simplicity, accessibility, and sustainability.

Both simplicity and accessibility are due to the fact that for users it is possible to experience augmented reality from any browser and any mobile phone, and for developers the opportunity to create this kind of content using familiar technologies.

Sustainability is achieved using location-based augmented reality, which allows virtual models to be placed at any location, without the need to place markers that modify the landscape or signify any damage to nature.

5.0 Development

The software development process entails a set of steps followed to improve design and product management. It is also known as software development cycle (SDLC) (Wikipedia contributors, 2023). According to Great Learning Team (2022), the development cycle as part of the agile methodology follows the 5 Ds as core values. Define, design, develop, demonstrate and deliver.

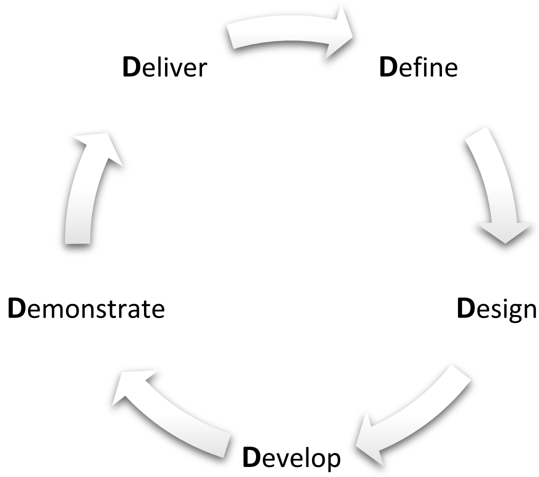

Figure 5 «5 Ds» Agile core values

5.1 Requirements and planning

In accordance with the agile methodology, the starting point for the development of an application is to identify the user's story and understand the problem.

As mentioned earlier, Stikk ut! seeks to increase the participation of young users in its tour offer. To address this, Tibe wants a proposal solution that involves the use of digital tools. Finally, the end users for this application are children who tend to show little interest on walking outdoor.

Outdoor activities have passed into the background as far as the interest of children is concerned. In recent years, they have shown a tendency to pursue activities that involve the use of technological devices, be it computers, mobile phones or video games. Although the participation of children in Stikk ut! increased from 2019 to 2020 (Figure 6), it still remains low. It is important to increase youth participation. Outdoor walks are part of Norwegian culture and Stikk ut! wants to instill in users the joy of walking, walking in cultural landscapes, discovering hiking areas, experiencing nature, and the individual's love of nature.

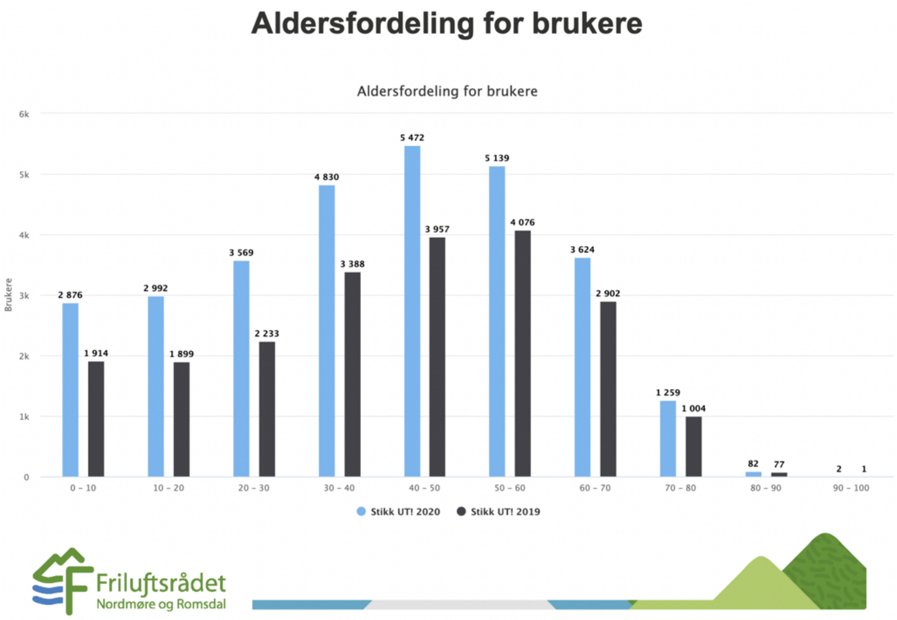

Figure 6 Age distribution of Stikk ut! registered users (Friluftsrådet Nordmøre og Romsdal, 2020)

Taking into account the values and objectives of Stikk ut!, and the interests of the end users, the requirements for the development of this proposal part from the following key points:

- The interest in technology by children.
- Most of children older than 7 years are already familiar with smartphones.
- Augmented Reality is a technology that provides interaction and combines the real and digital worlds. This combination is suitable to digitalize an outdoor activity.

- Location-based AR uses GPS to activate digital content, which means that virtual objects can be rendered anywhere. Hence nature will not be altered by markers.

Smartphones have the technology required for the implementation of AR. Most of them have GPS and cameras. Moreover, users have prior knowledge about the basic operation of these devices. Hence, the solution must be tailored for mobile phones, and it should be cross platform. The application must comply with the key elements of augmented reality. That is, the real world and the virtual world should be combined subtle and efficient manner. In addition, virtual objects must be registered in 3D, and the interaction must take place in real time. Thus, the application will be able to efficiently render virtual elements located at different points of interest along the trails of Stikk ut!

Among the values of Stikk ut! there is a sense of environmental responsibility and sustainability. They aim for youth to be more active and also to be interested in nature. The application must adhere to these goals and values.

Finally, the mobile application should be straightforward, easy to use, and accessible. It must also be scalable, allowing for the installation of additional features and managing the tours where it will be implemented.

5.2 Design

In this stage the structure of the application will be defined, in a way that it meets the requirements on the previous stage. The 5 principles for AR designing, as seen in the lectures of Extended Reality by Professor James Wen (2023), will be considered. These principles are described as follows.

1. Sense: the design must be visually simple, avoiding overcrowded sceneries while incorporating detail and depth. To achieve an effective AR mobile display, only the most relevant information should be added. In addition,

the interface techniques should fit the situation. Finally, the objects on the screen should be optimally placed.

2. Ponder: design taking into account the situation awareness. When designing for cognition, associative cues can be added to make the user ponder and deduct information.
3. Act: design to allow the user to act. The functional elements should be made obvious and helpful.
4. Comfort: the physical capabilities of the user, as well as the limits of the surroundings, should be considered. AR must be ergonomically built so that physical interaction does not cause discomfort or compromises the user's safety.
5. Environment: because of AR applications use tracking systems and cameras they may potentially invade third parts privacy. This should be addressed when designing for AR.

5.2.1 Sketching

The theme for this prototype, as suggested by Tibe, is the care of nature. The intention is to give users the message of how important is to keep the trails free of garbage. The application is a scavenger hunt-like game in which the player must find tokens or hints, in order to reach a certain goal. These tokens are virtual garbage that a monster has left in the wild. Users are tasked to follow the garbage traces and prevent the monster from polluting more. The points of interest are indicated through riddles that provide a challenging dynamic to the game.

To avoid overloading the augmented reality scene, the riddles are displayed in a common website interface. The user gets directions and explores the trail naturally until the point of interest is identified. It is then that the augmented reality feature can be activated, and the area can be scanned to collect the token, that is the 3D model. However, it is not always the case that the user can solve the riddle and know where the point of interest is.

As a solution for this situation, a visual element is added to indicate to the user whether or not he is at the correct spot. With this element, the proximity to the point of interest can be checked on the screen at any moment, eliminating the need to maintain a fixed view of the device while walking. Once found, the token is collected by touching the screen. Touching the screen is assumed to be an obvious interaction when it comes to mobile phones. By touching the token, the next riddle is displayed, and the process is repeated until the monster is caught. When the monster is caught, the success is confirmed with a message to the user and the game is over.

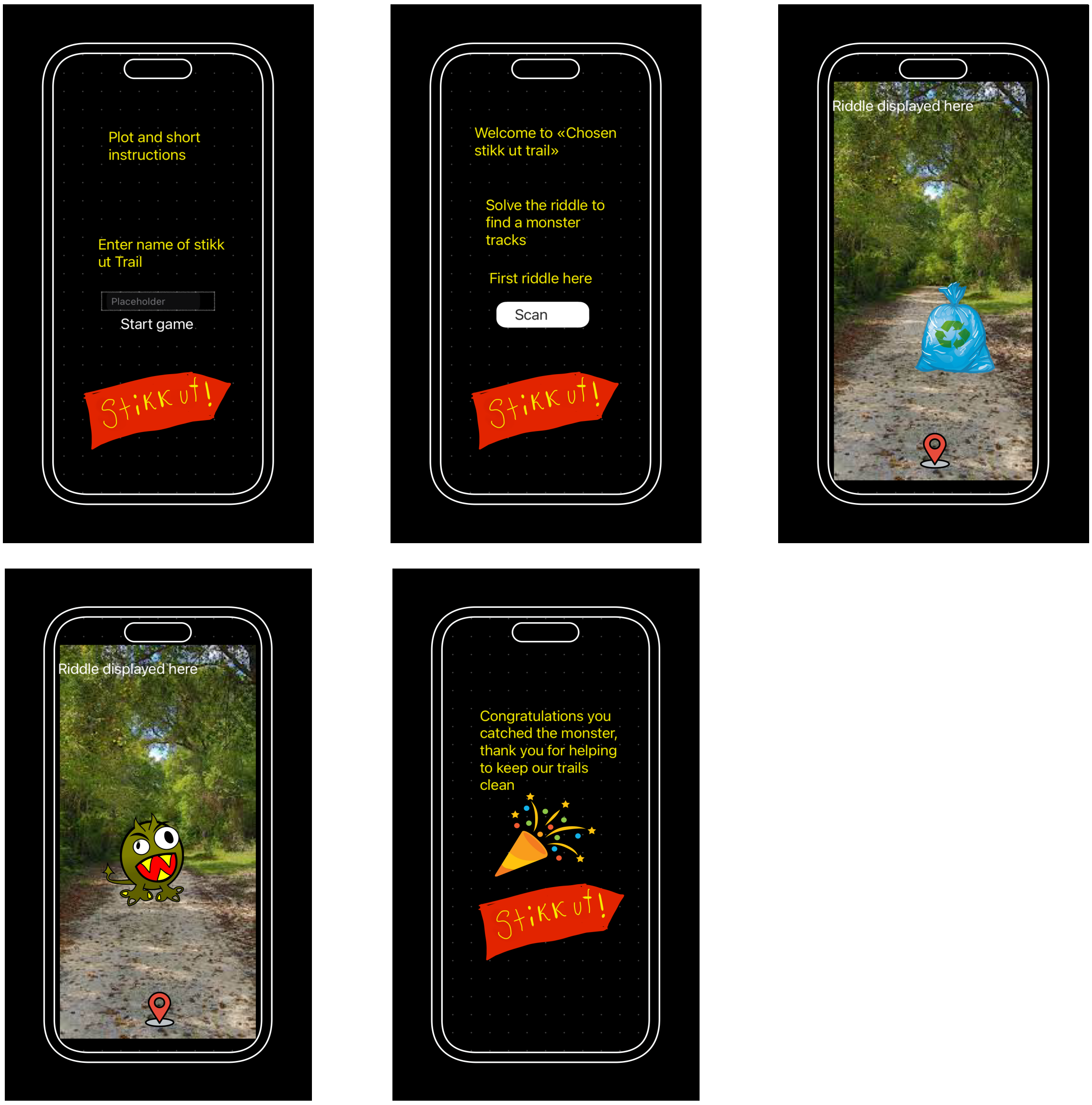

Figure 7 Sketch of the monster hunt application

5.3 Programming

Once the requirements, design, and logic of the Monster hunt game were decided, the programming phase was started. The following flowchart was used as a guide. This gave a general overview of how to build the functionality of the application and also served to define most of the tasks that needed to be done and assign them to cards on the Kanban board.

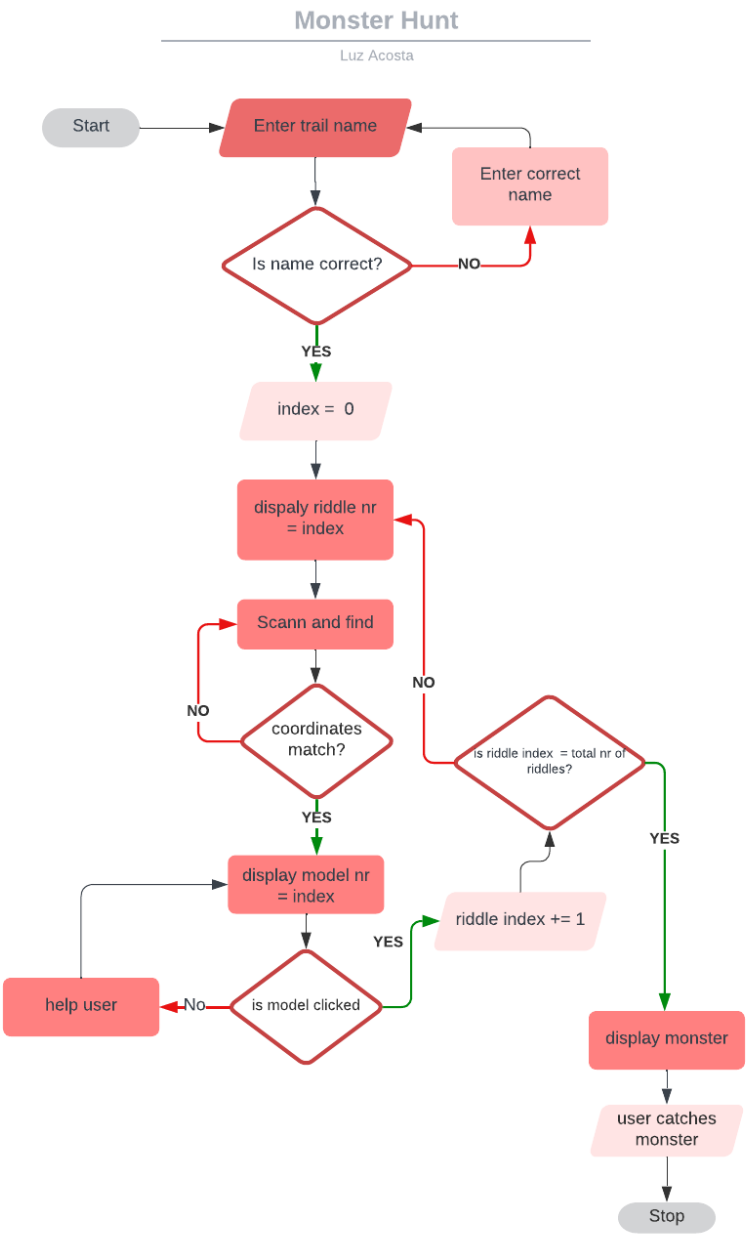

Figure 8 Monster hunt flowchart

The starting point was to define what data was necessary for the game and how it should be managed. A treasure hunt game has a set of riddles that will be solved in a sequence. The first riddle leads to the second, the second leads to the third, and so on. This indicated that the riddles needed to be stored somewhere, so they could be accessed in order to follow a sequence.

Each riddle is displayed on a point of interest, a place along the trail that the user has to find. To each point of interest belongs a riddle and a set of geographic coordinates that indicate the location where a virtual object will be placed. Furthermore, a set of points of interest belongs to a specific trail. The approach taken for the storage of these values was to create a separate JSON file and assign each tour to an object. JSON is lightweight and versatile; the data can be stored hierarchically and be queried using JavaScript from other files.

Once the data was organized and ready for use, the next stage in the programming phase, was to set focus into studying the documentation of the AR.js and A-Frame libraries. This was a critical step in understanding how to render virtual objects using these tools. The first task was creating simple elements, such as prisms, and experimenting with them (Fig. 9). Various tests were then carried out in order to learn how these virtual objects could be placed on the screen, their size, position, and illumination effects. Similarly, the accuracy of the chosen tracking system was checked. Testing helped to determine the necessary functions to obtain the desired results. For instance, tokens had to appear exactly at the indicated point of interest and only one token had to be shown at a time, preventing subsequent clues from being revealed as the user can see them in the distance.

Figure 9 First AR tests using a simple 3D prism

The GPS tracking can be enabled by the AR.js component “gps-new-camera”. This component must be added to the A-Frame camera entity. It allows for the camera's position and rotation to be handled, and it is used to determine in which direction the user is pointing the device (AR.js Documentation, n.d.). The "gpsMindistance" attribute was also added to the component to reduce jumping effects on the model caused by frequent small changes in position. Setting this allowed to control how far the device must move in meters to generate a new GPS event. The minimum distance was kept with its default value, which is 5 meters. AR.js has also the property “maxDistance», which functionality is to hide the AR content if the distance from the point of interest to the user is higher than the set value. However, this integrated function was inaccurate, since objects that were placed at greater distances than the set value could still be observed. This inaccuracy caused a couple of issues. First of all, the models appeared long before the user was in the correct location, giving no sense to the solution to the riddle. Second, the next models could be seen from far away before the user could read the subsequent riddle. It was obvious that another approach was required to address this.

In order to control where and when the virtual objects appear, the same principle from the “maxDistance” property was applied. That is, virtual objects are displayed if the user is within a preset distance from the indicated coordinates. This could be done with an if statement that checks if the user is located within a set radius from the point of interest. The distance between the user and the point of interest is a geographical distance and needs to be calculated considering the curvature of the earth. Hence, the computation was done using the "haversine" formula, which calculates the distance over the earth´s surface.

Haversine formula:

$$a = \sin^2(\Delta\varphi/2) + \cos\varphi 1 \cdot \cos\varphi 2 \cdot \sin^2(\Delta\lambda/2)$$

$$c = 2 \cdot \mathrm{atan2}(\sqrt{a}, \sqrt{(1-a)})$$

$$d = R \cdot c$$

Where φ is latitude, λ is longitude, R is earth's radius (mean radius = 6,371km). (Chris Veness, www.movable-type.co.uk, n.d.)

The JavaScript version of the haversine formula used in this application is shown in the following code snippet (tshunt/js/ar.js line 21).

```
const Distance = ([lat1, lon1], [lat2, lon2]) =>
    const earthRadius = 6371;
    const dLat = (lat2-lat1) * Math.PI / 180;
    const dLon = (lon2-lon1) * Math.PI / 180;
    const a = Math.cos(lat1 * Math.PI / 180) * Math.cos(lat2 * Math.PI /
180) * Math.sin(dLon/2) * Math.sin(dLon/2)+ Math.sin(dLat/2) *
Math.sin(dLat/2);
    const c = 2 * Math.atan2(Math.sqrt(a), Math.sqrt(1-a));
    const distance = earthRadius * c;
    return distance;
}
```

The next step was creating the start page (index.html) with a short introduction to the game and a form that prompts the user to enter the tour name. The user input is then verified to make sure that the user enters a valid name. After entering the required data, the user is redirected to the riddle page where one riddle is shown at a time. The riddle.html file is populated in a dynamic way using HTML DOM (Document Object Model) and JavaScript, which also fetches the corresponding data from the JSON file. The button “find” opens the ar.js file which activates the camera and displays the 3D object when the user is in the right spot.

When the 3D model was successfully rendered, the next task was to add interaction to it. The common input mechanism in a mobile phone is touch. Originally the plan was to add a button that could be touched as a sign that the user had seen the model. However, this solution was too ordinary since the button had to appear at the same time as the model and it did not add a sense of physical interaction with the AR content. Thus, the ideal interaction would be to touch the model directly.

Diving deeper in the A-Frame documentation, it was found that enabling clicks directly on the 3D model was possible using ray casting. The A-Frame raycaster component performs line-based intersection checking. Raycasting is the process of extending a line from an origin in one direction to another and determining if that line overlaps with other things. The three.js raycaster is used in the raycaster component. The raycaster checks for intersections against an object and emits events on the entity when it detects or clears intersections (Raycaster – A-Frame, n.d.). In the ar.html file, an extra camera primitive was created, and the a-cursor primitive is added as a child of the new camera, in order to use the raycaster. According to the documentation of A-Frame a-cursor allows for interaction on devices that do not have hand controllers. For it to work, the cursor component must also be added to the scene with the property of rayOrigin equal to mouse. This component listens to events and maintains track of what is hovered and pressed.

Once the models were touchable, it became possible to fire an event. Such an event would be to redirect the user to the next riddle. In order to handle events a new component has to be registered and added to the entity that contains the 3D model. The mechanism of an A-Frame component is similar to an HTML attribute and its value. The attributes indicate component names, while their values provide component data.

The registration of the custom component was done as shown in the code snippet below (tshunt/js/ar.js line 2). The component was given the name “collect”.

```
AFRAME.registerComponent('collect', {
      init: function(){
            this.collect = function(){
                  location.replace("./riddle.html")
                  if (sessionStorage.index) {
                    sessionStorage.index = Number(sessionStorage.index) +
1;
                  }
                  else {
                    sessionStorage.index = 1;
                  }
      }
            this.el.addEventListener('click', this.collect);
      },
      remove: function(){
            this.el.removeEventListener('click', this.collect);
      }
});
```

As it can be seen in the code above, the function in the “collect” component, not only redirects to a new riddle but also starts an index. This index was needed, for the system to display one riddle and one model at a time. The best approach to create and update the index was to do it along with the event triggered by touching the model. When the model is touched the index is updated. In order to facilitate access to this index from different files it was saved in a session storage.

To end the game, an if statement checks whether the index is equal to the length of the list that contains the points of interest in the applied tour. If so, the user has reached its goal. The monster of the garbage is displayed, and it is captured in the same way that its traces were collected. The event triggered by touching the monster is to display a completion message.

5.4 UI and UX

An important part of the programming phase is building a graphical layout to make the application visually cohesive in an aesthetic and functional way (Ispiryan, 2022). The chosen interface theme is nature, which is ad hoc to the environment where the monster hunt game takes place. The application style was developed, using the CSS framework. A nature-inspired background was chosen for the parts of the application with a common web format (index.html and riddle.html). In these parts, instructions and riddles are displayed procuring to limit the amount of text as much as possible and highlighting this information in a container box.

Regarding the style for the part that contains augmented reality (ar.html), this was minimal. Following the "sense" principle for AR design mentioned earlier in this chapter (5.2 Design), the scene was kept as simple as possible, letting reality be shown through the camera of the device. However, some elements necessary for the user experience were included here. The riddle was displayed in a smaller and discrete format on the top of the screen. The intention of this was to allow the user to read it again while trying to solve it when the camera is open. Another element included here is a button placed on the bottom of the screen, which function is to guide users to find the points of interest. This element is a circle that resembles a light that changes color, according to the distance between the user and the point of interest. The color of the circle is red if the user is far from the point of interest, changes to yellow as the user is getting closer, and turns green when the user is in the right spot. Furthermore, the circle contains a question mark in it, and it can be clicked to display extra guidance for the user.

Lastly, another important part of the design was the models chosen for the game. On its documentation, A-Frame recommends using glTF models due to their reliability. GlTF (Graphic language transmission format) is a format that provides a powerful set of features, such as skeletal structure, animation, and scene information (light sources and cameras). These models can be created from scratch or downloaded from different sources. For this application, two models found on Sketchfab were used. The garbage left by the monster (Fig. 10) and the monster itself (Fig. 11). The models are added to the scene using an "a-entity" primitive, where different components and properties can be added to edit features such as scale, rotation, and lighting among others.

Figure 10 Plastic bottle glTF model (Sketchfab, 2020)

Figure 11 Garbage monster glTF model (Sketchfab, 2019)

The source code for the Monster hunt application is available at:
https://github.com/luza83/bc_oppgave.git

6.0 Testing

Testing the functionality and usability of the application was done along with the programming process. The use of Replit facilitated the testing process in a considerable way. This virtual environment allowed to test the application immediately after adding a new feature. At the beginning of the programming phase, most of the tests addressed the accuracy of the tracking system and how the models render on the screen. As the application evolved, the sequence of the riddles and the response of the interaction with the 3D objects were also tested. Both accuracy of tracking and the sequence of riddles required walking outdoors several times to try different situations. Examples of these situations are, the performance of the application if the device went into sleep mode, how long it took for virtual models to render after the light became green and how did the application work on different browsers.

After several test and debug cycles the application was ready to be tested on actual users. One of the Stikk ut! tours known as “Retiro” was used to perform this kind of test.

Due to limited time, this test was applied to only eight children, whose ages ranged from 6 to 10 years. They played the game and were asked some questions at the end. The survey and its results are shown in the following table.

How old are you?	The ages varied from 6 to 10 years.
Have you heard of Stikk ut?	Only 3 of the 8 kids had heard about Stikk ut!
How often do you take a walk outdoors?	6 of them almost never go for walks outdoors, while the rest do it more often.
Do you like hiking?	Most of the children had a positive answer, only two of them were not sure if they like this activity.
Do you own a mobile phone?	Half of the participants had their own mobile device. The rest played the game using their parents' mobile phone.
Which model is the mobile phone you used?	Most of the participants played the game on Android, only two played on iOS. The devices using android were models from Huawei, Samsung, and Motorola.
Was it easy to play the Monster hunt game?	Most of the users reviewed the application as easy to use.
Would you like to try more Stikk ut! trails with a monster hunt game or a similar game?	The answer from all of them, was that they would like to play again a game like this when they go hiking.

Table 1 User survey

This was only a small experiment, and the number of users that tested the application does not represent a population. However, through observation and a small interview, it was possible to reveal both flaws and strengths in the application.

It could be observed that children had no problem using mobile devices, even if they do not own one. They all were interested in digital games.

The performance of the application was generally good in all the models. Both safari and chrome showed correct GPS tracking and rendered the virtual models without errors. There were only two exceptions. The first one was Huawei devices, even though performance was good, camera and location settings were hard to enable. Furthermore, this model showed the camera scene zoomed in, which did not allow the user to see the full field of view. The second exception was for the Motorola device, this was an old model. Tracking worked fine, but the virtual content was too slow to render. This situation caused frustration on the user.

At the start of the game, it was a little hard for them to understand that the garbage they were looking for was virtual garbage. Before they saw the first virtual garbage on the screen, they were attempting to take a picture of real garbage or to pick it up from the ground.

The participants understood the dynamic of the game and considered the application as easy to use. A couple of users thought that the hardest part of the game was solving the riddles.

All the tested users were satisfied with the application and the activity as a whole. They discovered places in nature, found real garbage, and showed excitement when they found and catch the garbage monster.

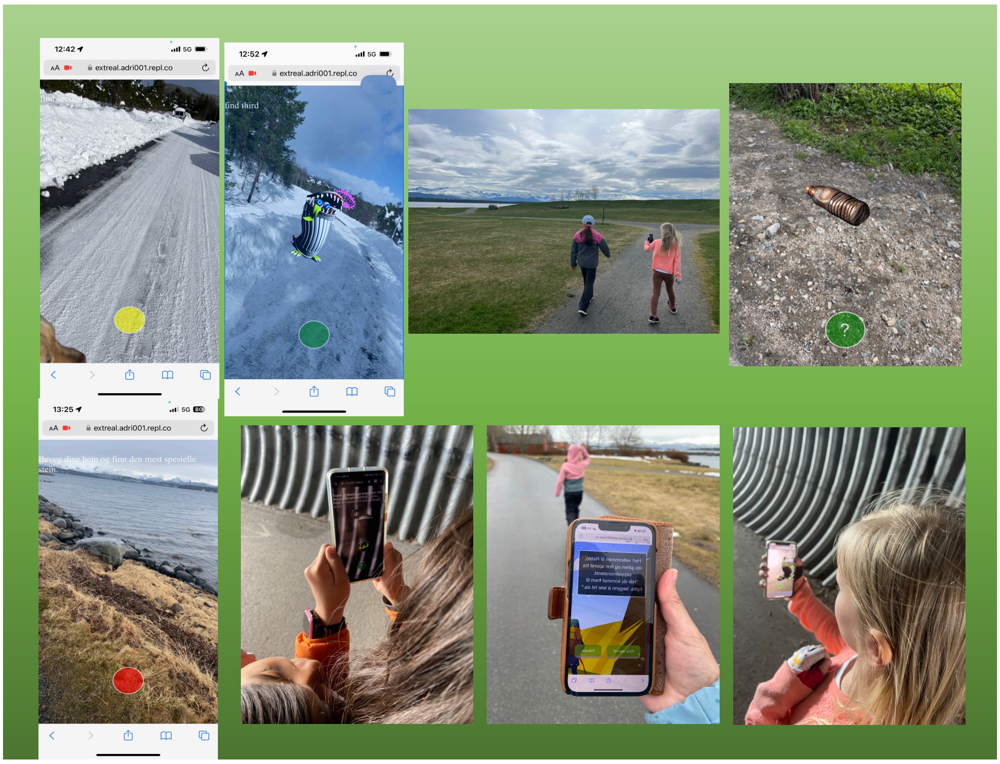

Figure 12 Documented images during testing

7.0 Conclusion

The main focus of this project was to find a way to encourage children to engage in physical activity in nature using augmented reality. Thanks to the technological development that smartphones have reached and the interest in digital games among children, this immersive technology proved to be the right one to digitalize and enhance an outdoor activity such as hiking. Observations collected during testing revealed that users had the chance to fully perceive reality between each point of interest. They had the opportunity to discover and enjoy nature as they were playing a game that made them complete the whole path in an exciting way.

The chosen framework AR.js showed great performance when it comes to GPS tracking and displaying AR content, both worked smoothly on most devices. Using a web-based solution was also pretty convenient for users, all they had to do to start playing was click on the link that had been shared with them. The performance of the application was in general satisfactory. However, there is room for improvement. Some small issues must be fixed, and new features may be introduced.

7.1 Further improvements and recommendations

The quality of the content and design are the key to the success of an application based on augmented reality (CrossComm, Inc., 2022). In this prototype, a simple design was used and only two models were imported from Sketchfab. Thus, the interface has great potential for improvement, components such as buttons and text could be made more visually attractive. In addition, it is recommended to use models designed exclusively for the application. For example, a unique monster can be designed for each tour. Based on what was observed during user testing, the most exciting item in the game was encountering the monster; enhancing the design of this item and adding animation effects will immediately upgrade the AR experience.

Defining the points of interest on a tour is one of the most time-consuming aspects of the Monster Hunt. This process requires walking along the trails and spotting places with peculiar characteristics that should be easy to recognize. Once this is done, finding a riddle that relates to the context of each point of interest requires quite a bit of creativity. Stikk ut! is an initiative that is run by volunteers. Based on this, active participants of this offer could be invited to suggest riddles for the game using the existing Stikk ut! registration system. After all, many of these participants are parents who would like their children to be more active.

Another feature that might be improved is the data sources used. The current approach is to store data in a JSON document, but other options, such as a database or an API for coordinates and 3D models, are feasible. By including this sort of functionality, the program would become more robust.

At the beginning of the project, it was intended to add a database in order to create user accounts. This would enable persisting data, so the user can keep access to the tours that have been completed. User accounts can also be used to create contests and events where the participants can win prizes by completing many tours or catching many monsters. Adding events like this would foster a sense of achievement and encourage continued participation.

The Monster Hunt prototype is an application that has all the possibilities and versatility of the web. Because web-based applications are easy to update and maintain, applying the mentioned improvements can be quite simple.

A risk analysis and statistical research can also be added to this project. These processes can provide the necessary information to improve the application and its content. A risk analysis would highlight the application's strengths and limitations. Whereas statistical research would provide more detailed information about the end user's preferences and expectations. Furthermore, performing these types of research might forecast if such an approach is feasible.

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Other links and resources

Source code:

https://github.com/luza83/bc_oppgave.git

Monster hunt application:

https://extreal.adri001.repl.co

Kanban board in Trello:

https://trello.com/invite/b/tXS8PoDj/ATTI10dec4e226273c6a30b044c8d3aafda6CCA158F2/kanban

Diagramming app for Flowchart and UML:

https://www.lucidchart.com/pages/

Sketch app for UI/UX:

https://getmockup.app

Citation tool:

https://www.scribbr.com/citation/generator/

Developing information and tutorials:

https://www.w3schools.com/html/default.asp

https://www.geeksforgeeks.org/

https://developer.mozilla.org/enUS/docs/Web/API/Document_Object_Model

https://www.codecademy.com/learn/learn-a-frame