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ONLINE VISUALISATION OF HIKING ACTIVITIES

Diploma thesis

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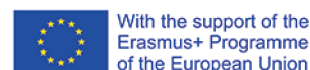
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ANOTATION

The main objective of the master thesis is to develop web-based tourism application that harnesses the potential of web-based geographic information systems (GIS) to enhance outdoor leisure experiences. The app is specially designed to help hikers plan tours based on their personal preferences and requirements. It contains a comprehensive range of information on hiking routes, public transport, parking, attractions, viewpoints and restaurants, all accessible through a user-friendly and interactive interface.

The application is developed using Node.js and the ArcGIS API (ArcGIS Maps SDK for JavaScript), which requires a significant level of programming skills, as well as knowledge of data science and database administration. Node.js is a popular back-end development platform, and the ArcGIS API is a powerful tool for geospatial mapping and analysis. Together, these technologies provide a solid foundation for the development of web-based GIS applications, such as the hiking application described in this research.

One of the main advantages of the application is that it is based on an open-source platform, which means that it is accessible to both users and developers. This availability ensures that the app can be updated and expanded over time as more trails and outdoor destinations are added to the database. In addition, the app uses 3D scene design to offer users a visually pleasing and immersive experience.

The study area for this application is the Nockstein and the Gaisberg in Salzburg, Austria. However, the app has the potential to expand globally, covering trails in different parts of the world. This hiking application is a testament to the potential of web-based GIS and a valuable resource for hikers looking to explore new trails and outdoor destinations. With this app, hikers can plan their hikes more efficiently, discover new trails, and enjoy safer, more enjoyable outdoor experiences.

KEYWORDS

Keywords – hiking, visualisation, trials, simulation, web-app, ArcGIS API, Node.js

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Hereby, I declare that this piece of work is entirely my own, the references cited have been acknowledged and the thesis has not been previously submitted to the fulfilment of the higher degree.



24/05/2023, Olomouc, Czechia

Ravi Kumar PANDEY

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ASSIGNMENT OF DIPLOMA THESIS

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Theses guidelines

The main objective of the master thesis is to propose, design, and develop a web-based platform to visualize interactively simulated hiking activities. The student will analyse available visualisation methods (2D/3D, colour schemes, animations, multimedia, etc.), web technologies (mapping libraries), and datasets. A Decision-making process based on spatial parameters will be implemented – the application will help hikers decide on their hiking paths, energy requirement, and place-making/scenic/resting locations. Finally, a potential for hiking-based tourism activities will be done by spatial analysis of the hotspot locations in between the hiking trails.

The student will attach all the collected datasets and all the animations to the thesis in digital form. The student will create a website about the thesis following the rules available on the department's website and a poster about the diploma thesis in A2 format. The student will submit the entire text (text, attachments, poster, outputs, input and output data) in digital form on a storage medium and the text of the thesis in two bound copies to the secretary of the department.

Extent of work report: **max 50 pages**
Extent of graphics content: **as needed**
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- Fu, P., & Sun, J. (2011). *Web GIS: principles and applications* (pp. 89-114). Redlands: Esri Press.
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Content

LIST OF ABBREVIATIONS	X
INTRODUCTION	X
1 AIM AND OBJECTIVES	10
1.1 Aim	10
1.2 Objectives.....	10
2 STATE OF ART.....	12
2.1 Defining Online Visualization	12
2.2 Benefits of Online Visualization for Hiking Activities	13
2.3 Design Principles for web Cartography	13
2.4 Current Research on Online Visualization for Hiking Activities.....	17
2.5 Importance of Online Visualization for Hiking Activities	19
2.6 Technical aspects in web cartography and APIs	21
3 METHODOLOGY	23
3.1 Work stages.....	23
3.1.1 Defining users.....	24
3.1.2 Defining Specific Information.....	25
3.2 Study Area selection	27
3.3 Data Collection	29
3.4 Selection of APIs	29
3.5 Technical engagements	31
3.6 Development of the web application	32
3.7 Methods of the User Research	33
3.7.1 Questionnaire	33
3.7.2 Interview.....	33
3.8 Overall Methodology.....	33
4 IMPLEMENTATION OF THE MAP LAYERS TO SUPPORT HIKE PLANNING	34
4.1 Implementation of Prototype	34
4.1.1 Datasets and APIs.....	34
4.1.2 Client-Side User Interface.....	35
4.2 Evaluation of Prototype	45
5 RESULTS AND DISCUSSION	47
5.1 Participant’s overview	47
5.2 Participant’s Evaluation	49
5.3 Feedback and suggestions	51
5.4 Interviews.....	52
5.5 Results of analysis	53
5.6 Further Discussion	54
6 CONCLUSION	57
REFERENCES AND INFORMATION SOURCES	
ATTACHMENTS	

LIST OF ABBREVIATIONS

Abbreviation	Meaning
API	Application Programming Interface
GPS	Global Positioning System
DBMS	Database Management System
UI	User Interface
GIS	Geographic Information System
JSON	JavaScript Object Notation
NPM	Node Program Manager
JPEG	Joint Picture Experts Group
PNG	Portable Network Graphics
RGB	Red Green Blue (colour model)
SDE	Spatial Database Engine
SHP	Shapefile
SQL	Structured Query Language
GIT	Global Information Tracker
OSM	Open Street Map
WFS	Web Feature Service
JS	JavaScript

INTRODUCTION

Hiking is a popular outdoor activity that has increased in popularity in recent years, with more and more people looking for new and exciting places to explore. Hiking is a recreational activity that involves walking or trekking in natural environments, such as mountains, forests, and parks. The popularity of hiking has grown in recent years due to its health and environmental benefits, as well as its social aspect, allowing people to connect with nature and with each other. With the advent of technology, hikers now have access to a wide range of tools and applications that help them plan, track and share their hiking activities. One of the features of these platforms is the online visualization of hiking activity.

Online visualization is used in hiking to provide real-time information about the hiker's location, speed, altitude, and other key parameters. This information is displayed on a digital map, which allows hikers to monitor their progress and make informed decisions about their route. In addition, online visualization provides a visual representation of the data, making it easier for hikers to understand and interpret. This visualization can also be used to compare different routes and to find the best path for a specific type of hiking activity, such as backpacking or mountain climbing.

The idea is creating a web-based platform to visualize interactively simulated hiking activities that will help the new (in the city) hikers decide their hiking paths, energy requirements, and place-making/ scenic/ resting locations. This web application will also be helpful for the urban local bodies to take a look at potential hiking-based tourism activities by analysing the hotspot locations in between the hiking trails.

The use of online visualization in hiking provides several benefits for hikers, including:

1. **Improved Safety:** Online visualization allows hikers to monitor their progress and track their location in real-time. This helps to reduce the risk of getting lost or stranded and can be particularly useful in remote areas.
2. **Better Route Planning:** Online visualization provides a visual representation of the hiking route, making it easier for hikers to plan their route and find the best path for their activity.
3. **Increased Awareness:** Online visualization can be used to display key data about the hiker's performance, such as speed, altitude, and distance travelled. This information can help hikers to become more aware of their physical condition and make adjustments to their route accordingly.
4. **Sharing Experiences:** Online visualization also allows hikers to share their experiences with others. Hikers can share their routes, performance data, and photos with friends and family, allowing others to experience their adventure.

From the implementation point of view, both 2D and 3D scene are placed along with the hiking paths and point location of the scenic location and resting place. The data will be a combination of both vector and raster so that it can have more feasibility for the implementation purpose and vector data would be a combination of OSM and self-prepared/ observed paths and point location. The energy simulation will be based on a colour theme as a general hiking requirement. During the testing, observe how participants interact with the visualization and take note of any issues or problems they encounter. Encourage participants to think aloud as they use the visualization, so you can get insight into their thought processes and decision-making.

1 AIM AND OBJECTIVES

1.1 Aim

The aim of the thesis is to create a web-based platform for hiking activities, which will help the potential hikers to analyse their hiking track by various assessment parameters.

1.2 Objectives

Visualizing 3D terrain and its factors is crucial and widely used. It has huge potential for better serving humanity using GIS applications.

An online hiking visualization aims to show users their trails, distance, and elevation for tracking progress, planning hikes, and sharing experiences. It may also provide information on popular routes, trail conditions, and weather to aid hike planning. Online visualization also offers insights into usage patterns (e.g., popular times and trails) to help park managers and organizations plan outdoor recreational spaces.

Online visualization refers to the display of data and information in a visual format through the use of digital tools and platforms. This can include interactive maps, charts, and graphs. By using online visualization, park managers and organizations are able to gain valuable insights into usage patterns of outdoor recreational spaces, such as the most popular times and trails. This information can help inform decision-making around resource allocation, infrastructure development, and overall planning of these areas. The visual representation of data and information can also assist in effectively communicating these insights to stakeholders, promoting informed decision-making and collaboration.

The overall aim is further divided into two major objectives: “Data Phase” and “Visualization and evaluation phase”

I. Data phase: objective I
Defining and designing the data acquisition process.

Research questions:

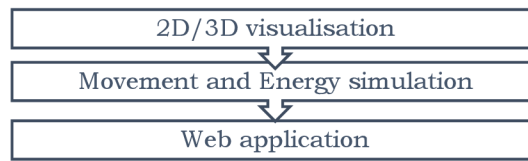
- a) For a decision support system aimed at travelers who are interested in hiking, what information is pertinent to make informed decisions?
- b) Which APIs are suitable and applicable to a hiking-focused decision support system, and what requirements must the APIs meet?

II. Visualization and evaluation phase: objective II
Visualizing and evaluating decision-relevant web map layers.

Research questions:

- a) What are the available web mapping applications, and how do they aid in the decision-making process for travelers?
- b) What are the optimal design features for map elements to best assist travelers in their decision-making process?

Major Components for the objectives



One potential objective for an online visualization of hiking activities could be to provide users with a visual representation of their hiking experiences, such as the trails they have taken, the distance they have covered, and the elevation they have gained. This can help users keep track of their hiking progress, plan future hikes, and share their experiences with others. Other objectives could include providing information about popular hiking routes, trail conditions, and environmental factors such as weather, to help users make informed decisions about their hiking plans. Additionally, online visualization tools can also provide insights into patterns of usage, such as the most popular times of year for hiking and the most popular trails, to help park managers and land conservation organizations better understand and plan for the use of outdoor recreational spaces.

To achieve the objective of online visualization of hiking activities, the following steps can be taken:

- ❖ Gather data: Collect information on hiking routes, including GPS coordinates, elevation changes, and other relevant details.
- ❖ Store data: Store the data in a database or file format that can be easily accessed and manipulated.
- ❖ Create a user interface: Design a user-friendly interface that allows users to view the data on a map, see statistics on the hike, and interact with the data in other ways.
- ❖ Map the data: Using a mapping library, display the hiking routes and other data on an interactive map.
- ❖ Visualize data: Create charts, graphs, and other visualizations that allow users to see the data in a more meaningful way, such as a graph of elevation changes over time.
- ❖ Deploy the application: Publish the application online so that users can access it from any device with an internet connection.
- ❖ Maintenance: Regularly update the data and make improvements to the user interface as needed to ensure a positive user experience.

This study will contribute to the understanding of online visualization techniques for hiking activities by exploring the types of techniques used, the perceptions and experiences of hikers, and the effectiveness of these techniques in providing meaningful insights and information. The results of this study will provide valuable information for the development of new and improved online visualization tools for hiking activities, allowing hikers to better track and analyse their performance, plan their routes, and share their experiences with others.

2 STATE OF ART

The purpose of this chapter is to review the literature on online visualization for hiking activities. The chapter will begin by defining online visualization, followed by a discussion on the benefits of online visualization for hiking activities. The web mapping applications that help travellers make decisions about their sports travel, particularly for hiking is also included in this chapter. The chapter explains how to design effective web-based mapping applications by reviewing cartographic design principles. Additionally, the chapter discusses existing web mapping products that support travel-related decisions, such as planning routes and checking weather forecasts. By examining these existing products, the chapter identifies their strengths and weaknesses and opportunities for improvement. The chapter will then explore the current research on online visualization for hiking activities, highlighting the research questions, methods, and findings. The goal of this chapter is to provide an understanding of web-based mapping applications designed for hiking and outdoor sports, and to help people make informed decisions about their travels.

2.1 Defining Online Visualization

Online visualization refers to the use of interactive and dynamic maps, photographs, videos, and other multimedia to represent geographic information on the internet. Online visualization is widely used in various fields, including tourism, education, and environmental planning. In the context of hiking activities, online visualization is used to provide hikers with a better understanding of the trails, surroundings, and facilities, enabling them to plan their hiking trips more efficiently.

The article from Esri (Goodchild, et al., 2015), about how Web GIS can change the way we access and analyze geospatial data. One important part of this is online visualization, which allows users to interact with data in real-time and get a better understanding of spatial relationships. According to a study by (Andrienko, et al., 2007) online visualization is a critical feature of modern GIS systems. The study highlights the importance of online visualization in enabling users to explore and analyze data more effectively, and to communicate their findings to others in an intuitive and interactive manner. Web-based mapping tools such as Leaflet and ArcGIS Online are cited as examples of platforms that support online visualization and enable users to create and share maps with ease.

According to (Zhang, et al., 2022), the review begins by discussing the growing popularity of online learning platforms and the potential benefits they offer. The authors highlight the unique challenges faced by online learners, such as limited social interaction and the absence of physical classrooms. They argue that visualization can play a crucial role in addressing these challenges by creating immersive and engaging learning experiences. In this paper the author also described “taxonomy of online learning behaviors regarding”, showed in the Figure 1 below.

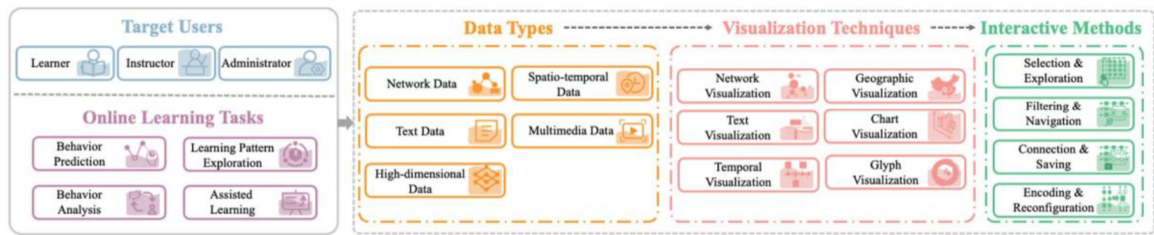


Figure 1 taxonomy of online learning behaviors regarding

In conclusion, the article by Esri emphasizes the potential of Web GIS to transform the field of GIS by making it more accessible, user-friendly, and powerful. Online visualization plays a crucial role in this transformation by providing users with an intuitive and interactive way to explore and analyze geospatial data.

2.2 Benefits of Online Visualization for Hiking Activities

Online visualization has many benefits for hiking activities. It can enhance the hiker's experience by providing them with a virtual tour of the trail, helping them to make informed decisions about the route, terrain, and weather conditions. Online visualization can also provide hikers with information about the facilities and services available along the trail, such as rest areas, toilets, and food vendors. This information can help hikers to plan their trips more efficiently and to avoid potential risks and hazards. (Association, et al., 2023)

(Hajdú, et al., 2021), present their work on the digital cartographic reconstruction of the 1897 'Mátra Guide', which is an important historical document of Hungary. The guide is a map of the Mátra mountain range and its surroundings, and it was originally published in 1897 by Károly Kerner, a geographer and cartographer of the time. The guide provided information about the mountain range, its flora and fauna, geology, and the surrounding settlements. It was an important resource for researchers and hikers alike, and it had a significant impact on the development of tourism in the region.

The guide was digitized using modern scanning techniques, and the resulting images were processed using GIS software. The authors used georeferencing techniques to align the digitized map with modern satellite imagery and topographic maps. They also applied various image processing techniques to enhance the quality of the scanned images and to correct for distortions caused by the original printing process.

The resulting digital reconstruction provides a valuable resource for researchers and historians interested in the history of the Mátra mountain range and its surroundings. It also provides a fascinating glimpse into the state of cartography and geography at the turn of the 20th century. The authors note that the digital reconstruction could be used as a basis for further research, such as the creation of 3D models of the landscape, or the analysis of historical land use patterns.

2.3 Design Principles for web Cartography

Web cartography refers to the creation and sharing of digital maps on the internet. It involves using design principles to create visually appealing and effective maps that are easy to use and understand.

Web mapping has come a long way since its inception in the early days of the internet. At first, maps were simply scanned and posted online as images, and users could not interact with them. However, over time, web mapping evolved to become more interactive and dynamic, with features such as zooming and panning. (ucgis, et al., 2017)

The introduction of Web 2.0 technologies allowed for the creation of user-generated maps, and communities could come together to share their maps for a variety of purposes. In recent years, multimedia content such as photos, videos, and 3D models have been integrated into web maps, making them even more engaging and immersive. Despite these advancements, scanned map images remain a common type of web map, and there are design guidelines for digital maps that consider the constraints of computer displays and web browsers. Overall, web mapping has evolved in response to advancements in technology, changes in user needs and expectations, and the growth of the internet.

- **Simplicity and clarity**

According to (Peterson, et al., 2005), Web maps should be simple and clear, with a clear hierarchy of information and a minimal design that highlights the most important features. This means using a limited color palette, easy-to-read fonts, and clear labeling of geographic features. The goal is to create a map that is easy to read and understand at a glance.

- **Cartographic rules**

According to (Cartographer, et al., 2011), Cartographic rules are essential guidelines for creating effective and visually appealing maps. According to the source "Web Map Concepts" by the State Cartographer's Office at the University of Wisconsin-Madison, several key rules can be identified. First and foremost, maps should strive for clarity and simplicity, ensuring that the intended message is easily understood by users. Additionally, the use of appropriate symbolization and color schemes is crucial in representing different features and conveying their significance. Consistency in the use of symbols, scales, and labels across the map also enhances readability. Proper spatial arrangement, including the placement of labels and legends, helps users navigate the map smoothly. Lastly, the source emphasizes the importance of evaluating the accuracy and reliability of data sources and ensuring that cartographic representations align with real-world phenomena. By adhering to these cartographic rules, map creators can produce high-quality and informative maps that effectively communicate spatial information to users.

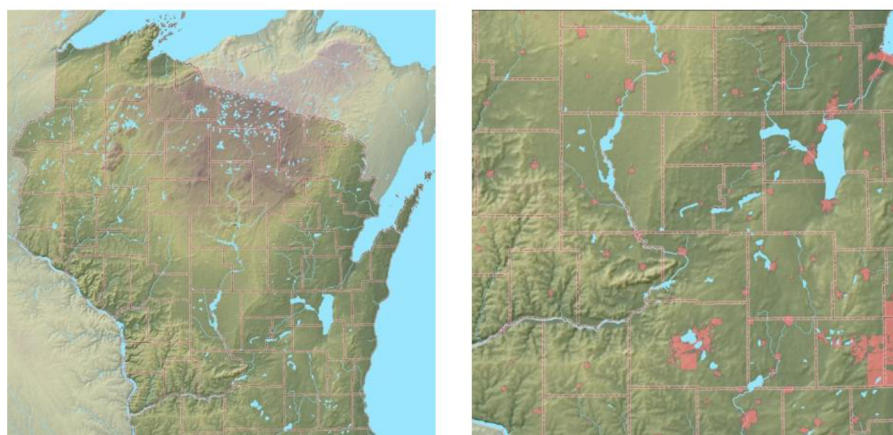


Figure 2 layer-based content selection



The Conflicts Along 1,172 Miles of the Dakota Access Pipeline

By GREGOR AISCH and K.K. REBECCA LAI | UPDATED Feb. 7, 2017

The Department of the Army announced on Tuesday that it will grant the final easement to finish the 1,172-mile Dakota Access pipeline. The easement will allow the pipeline to cross under Lake Oahe near the Standing Rock Sioux Reservation, which has been the center of protests for months.

Though legal disputes about water safety, Native American lands and eminent domain have delayed the project, the pipeline is nearly complete.

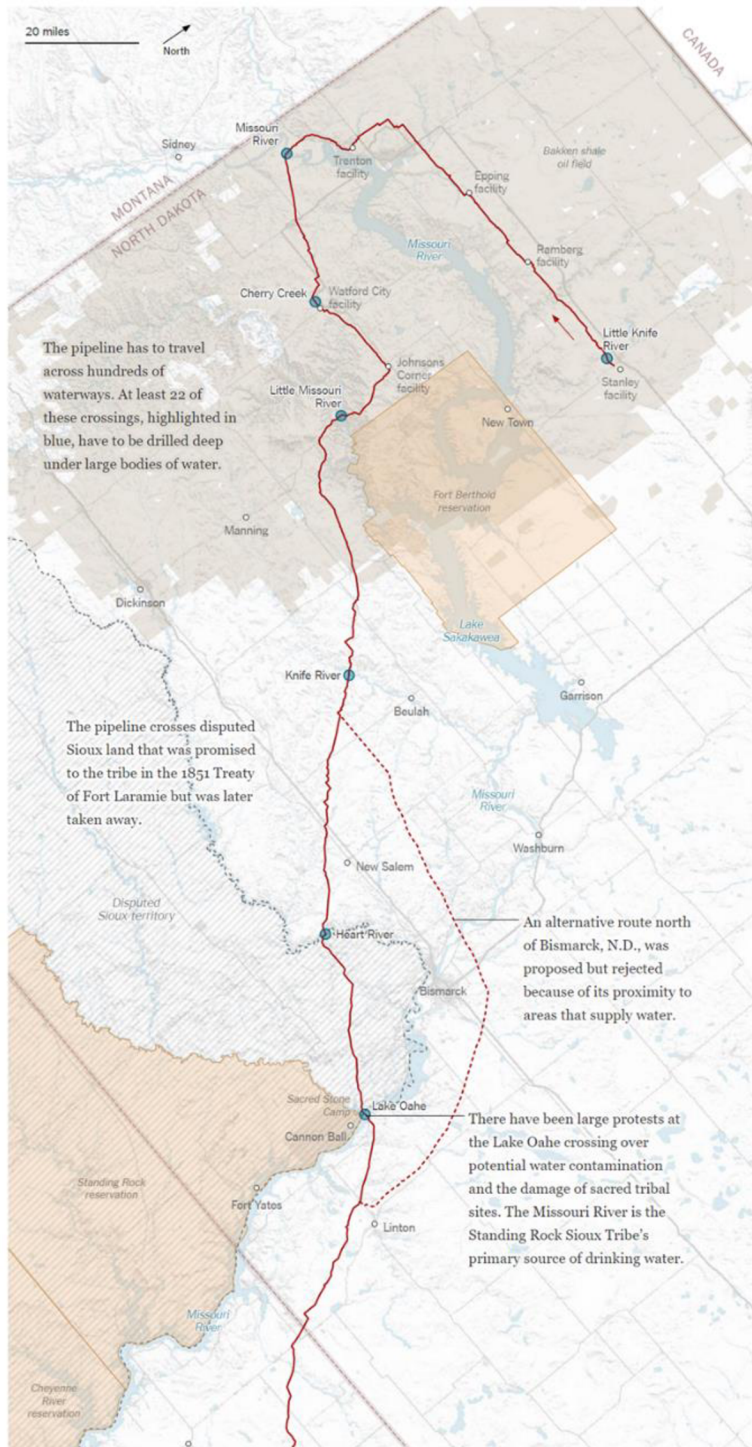


Figure 3 Static map portion, "Map by Gregor Aisch and K.K. Rebecca Lai, from The New York Times, last updated February 7, 2017. Reprinted with permission.

might focus on trails, water sources, and campsites, while a map designed for drivers might focus on highways, gas stations, and rest areas. (Tsou, et al., 2008)

- **Interactivity and cartography**

Web maps should be interactive, allowing users to zoom in and out, pan the map, and access additional information through clickable icons or pop-ups (containing text information and images in the form of PNG and JPEG). This helps users to explore the map in more detail and provides them with additional information that may not be visible on the map itself (Kalaitzis, et al., 2023). Additionally, Web maps should be designed with mobile devices in mind, since more and more users are accessing the internet on their smartphones and tablets. This means using responsive design techniques that ensure the map is easy to view and use on smaller screens. (Lateh, et al., 2005)



Figure 5 Interactivity with multimedia maps (CartouCHE, 2012)

2.4 Current Research on Online Visualization for Hiking Activities

Several studies have explored the use of online visualization for hiking activities. These studies have used various research methods, such as surveys, interviews, and observation. The studies have focused on different aspects of online visualization, such as its impact on the hiker's experience, the usability of the online visualization tools, and the effectiveness of the online visualization in providing hikers with relevant information.

In a study by (Wu, Li, et al., 2020), the authors investigated the impact of online visualization on the hiker's experience. The study involved a survey of 181 hikers in Taiwan, who had used an online visualization tool to plan their hiking trips. The study found that the hikers who had used the online visualization tool had a more positive experience than those who had not used the tool. The study also found that the online visualization tool helped the hikers to make informed decisions about the route, terrain, and weather conditions.

In another study by (Jean-Paul, et al., 2018), the authors explored the usability of online visualization tools for hiking activities. The study involved a series of workshops with hikers in Switzerland, who were asked to evaluate different online visualization tools. The

study found that the hikers preferred online visualization tools that were interactive, easy to use, and provided them with relevant information about the trail.

In a study by (Lee, et al., 2018), the authors investigated the effectiveness of online visualization in providing hikers with relevant information. The study involved a survey of 262 hikers in China, who had used an online visualization tool to plan their hiking trips. The study found that the online visualization tool was effective in providing hikers with information about the trail, such as the route, terrain, and facilities. The study also found that the online visualization tool helped the hikers to avoid potential risks and hazards.

An Evaluation by (Bleisch, et al., 2008) examines the effectiveness of using web-based 3-D visualization for planning hikes virtually. The study evaluates the usability and user experience of a web-based 3-D visualization application designed for planning hiking routes, and the development of a web-based 3-D visualization application that allows hikers to plan their routes virtually. The application allows users to explore terrain and elevation data, as well as view a 3-D model of the hiking trail. The study evaluated the effectiveness of the application by conducting a usability test with 25 participants. Additionally, the results of the study showed that the application was easy to use and provided an effective way for hikers to plan their routes virtually. The participants also reported that the 3-D visualization helped them to better understand the terrain and elevation of the hiking trail.

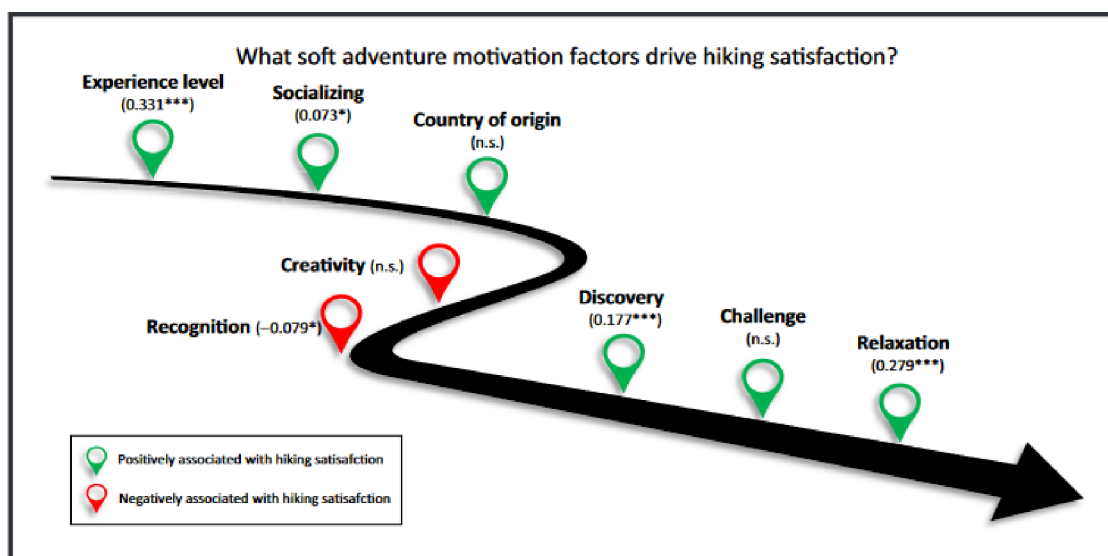


Figure 6 hiking satisfaction level. (Bichler, et al., 2021)

The study provides important insights into the potential of web-based 3-D visualization for planning hiking routes. The results suggest that the use of 3-D visualization can enhance the user experience and make it easier for hikers to plan their routes. The technology could be particularly useful for novice hikers who may not be familiar with the terrain and elevation of a hiking trail. The study also highlights the importance of user-centered design in the development of web-based applications. By involving actual users in the design process, developers can ensure that their applications are easy to use and effective. While there are limitations to the study, the findings suggest that web-

based 3-D visualization has the potential to be a valuable tool for hikers and outdoor enthusiasts. (Shang, et al., 2022)

Web-based 3D visualization tools have become increasingly popular in recent years, particularly for planning outdoor activities such as hiking. Another research from the same author in 2006, conducted to explore the usefulness of these tools for virtual hike planning. The review found that web-based 3D visualization tools can provide users with a combination of realistic and abstract information, which can help them make informed decisions about their hike. This information may include weather conditions, difficulty level, and points of interest along the route. One of the benefits of these tools is the ability to customize the level of detail. For example, some tools allow users to zoom in and out of the terrain to see different levels of detail, while others allow users to change the time of day to see how the lighting conditions change. This customization can help users better understand the terrain and environment, which can be particularly useful for planning hikes in unfamiliar areas. However, the review also highlighted some limitations of web-based 3D visualization tools. One of the main challenges is usability, particularly for users who are not familiar with 3D visualization or mapping tools. In addition, the tools can be resource-intensive, which can limit their accessibility for some users.



Figure 7 Monochrome reproduction of 3-D visualization used in the experiments. (Shang, et al., 2022)

Overall, the review suggests that web-based 3D visualization tools can be useful for planning hikes virtually. However, usability and accessibility are important factors to consider when using these tools. Future research could explore ways to improve the usability and accessibility of web-based 3D visualization tools for hiking and other outdoor activities.

2.5 Importance of Online Visualization for Hiking Activities

Online visualization tools have become an essential part of the hiking experience. These tools provide hikers with the ability to explore new trails, discover hidden gems, and plan their routes with ease. Online visualization tools offer a range of features, including 3D maps, real-time trail information, and user-generated content. These features help hikers to understand the terrain, distance, and elevation of the trail, as well as identify potential hazards and points of interest.

A study by (Liu, et al., 2021), examined the impact of online visualization tools on the hiking experience. The study found that hikers who used online visualization tools reported a higher level of satisfaction with their hiking experience. The study also found that hikers who used online visualization tools had a greater sense of control and confidence in their hiking abilities.

Another study by (Martínez-Graña, et al., 2017) explored the use of augmented reality (AR) technology for hiking activities. The study found that AR technology provided hikers with an immersive and interactive experience, allowing them to explore the trail in a more engaging way. The study also found that AR technology enhanced the educational value of the hiking experience, as hikers were able to learn more about the trail and its features.

A study conducted by (Pfaff, et al., 2007), analyzed the use of mobile applications in outdoor activities. The study found that mobile applications, including online visualization tools, are widely used by hikers. These tools provide hikers with the necessary information to plan their trips, such as weather conditions, trail maps, and terrain elevation.

Another study conducted by (Shelby, et al., 2016), analyzed the effectiveness of online visualization tools in outdoor activities. The study found that online visualization tools were effective in providing hikers with accurate and up-to-date information about the terrain, weather conditions, and trail maps. The study concluded that online visualization tools can enhance the hiking experience and increase the safety of hikers.



Figure 8 "Sequence of events. Users select the bottom button to begin, select Route, and then select Recent. Next, they select Osmanthus Trail and access important trail information, such as shelters, water, or user-tagged hazards" (Shelby, et al., 2016)

In a study conducted by (Laakso, et al., 2013), the authors developed a web-based application that provided hikers with information about the terrain, elevation, and weather conditions. The study found that hikers who used the web-based application had a more enjoyable hiking experience and were better prepared for the hike.



Figure 9 Sonic map for hiking (Laakso, et al., 2013),

A study conducted by (Rodriguez, et al., 2013), analyzed the use of virtual reality in outdoor activities. The study found that virtual reality was effective in providing hikers with a more immersive and interactive experience. The study concluded that virtual reality can enhance the hiking experience and increase the engagement of hikers.

2.6 Technical aspects in web cartography and APIs

There are several APIs available for web applications related to hiking activities. Here are a few popular ones:

APIs for Hiking and Trail Information:

- AllTrails API
- Hiking Project API
- Outdoor Project API
- National Park Service API
- Fatmap API

APIs are specifically designed to help hikers, backpackers, and other outdoor enthusiasts to find and navigate trails. Some of the popular APIs for hiking and trail information include AllTrails, Hiking Project, Outdoor Project, National Park Service, and Fatmap. AllTrails API provides information on hiking, biking, and running trails across the United States. It offers users details such as trail maps, reviews, photos, and difficulty ratings for each trail. Hiking Project API is designed to provide users with information on hiking trails and routes in the United States. It offers users features such as GPS-enabled trail maps, elevation profiles, and reviews. Outdoor Project API offers users details such as photos, maps, and guides for a variety of outdoor activities such as hiking, camping, and rock climbing. National Park Service API offers information on national parks,

monuments, and historic sites in the United States. It provides users with data such as park locations, descriptions, and visitor center details. Fatmap API provides users with 3D maps for hiking and skiing trails across the globe. (Favretto, 2010)

APIs for Maps and Location-Based Services:

- Google Maps API
- Mapbox API
- Leaflet API
- OpenLayers API
- OpenStreetMap API
- ArcGIS API

Maps and location-based services APIs are designed to provide developers with tools to build applications that can access geospatial data, location-based services, and map imagery. The most popular APIs in this category include Google Maps API, Mapbox API, Leaflet API, OpenLayers API, OpenStreetMap API, and ArcGIS API. Google Maps API is one of the most widely used location-based services APIs that provides developers with features such as maps, geocoding, and routing services. Mapbox API offers developers customizable maps, location-based search, and geocoding services. Leaflet API is a lightweight JavaScript library that enables developers to build mobile-friendly interactive maps for web applications. OpenLayers API is an open-source JavaScript library that allows developers to create web-based maps with features such as zooming, panning, and overlays. OpenStreetMap API is an open-source alternative to Google Maps API that provides developers with data such as street maps, points of interest, and routing services. ArcGIS API is a comprehensive mapping and location-based services platform that offers developers tools for building complex mapping applications with features such as geocoding, routing, and 3D visualization.

Summary of Key Findings

The literature on online visualization for hiking activities suggests that online visualization can enhance the hiker's experience by providing them with a virtual tour of the trail and relevant information about the trail, surroundings, and facilities. The literature also suggests that hikers prefer online visualization tools that are interactive, easy to use, and provide them with relevant information. Finally, the literature suggests that online visualization is effective in helping hikers to make informed decisions about the route.

Online visualization tools have become an essential part of the hiking experience, providing hikers with a range of useful features to plan and navigate their routes. These tools have been shown to enhance the educational value of the hiking experience, as well as provide a greater sense of control and confidence for hikers. However, there are some challenges and limitations that need to be addressed, including the availability and accuracy of data, as well as the accessibility of online visualization tools. Future research should focus on addressing these challenges and exploring new technologies to enhance the hiking experience.

3 METHODOLOGY

The topic of this thesis is the online visualization of hiking activities. The primary objective of this research is to explore the potential of using online visualization tools to enhance the experience of hikers by providing them with a comprehensive overview of their hiking activities. The methodology used in this thesis will provide a systematic approach to the research and ensure the validity and reliability of the findings. This study will adopt a mixed-methods research design, combining qualitative and quantitative research approaches to obtain a comprehensive understanding of the topic.

3.1 Work stages

The overall work is divided into seven major steps, which involve the initial process of data collection, as well as other planning, research, and development processes. User testing for fellow hikers and other specialists has been included in the overall process before finishing the application development process.

According to (Shakil, 2019) the overall stages have a hierarchical structure, progressing upwards from the base mechanism. The step-based bottom-to-top approach is shown in Figure 10 below.

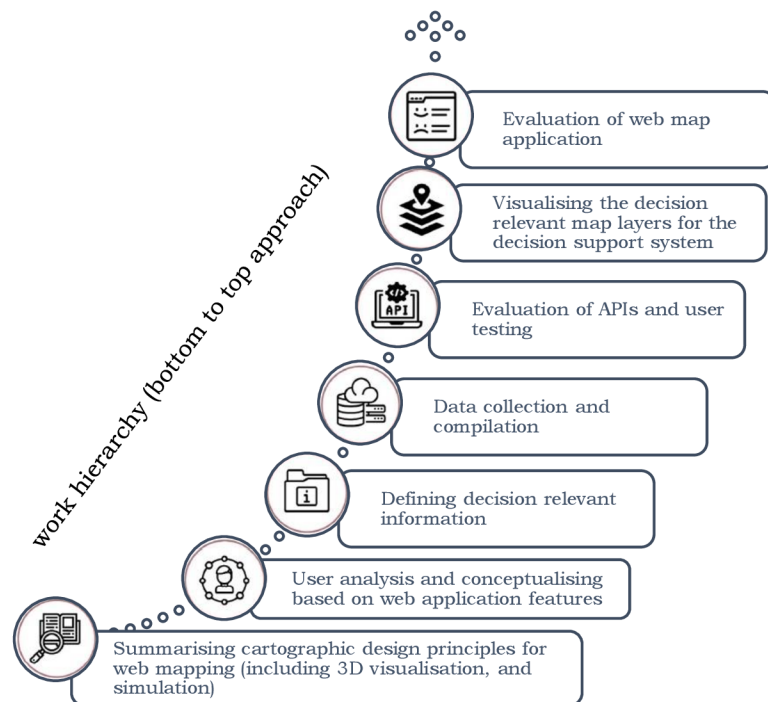


Figure 10 Methodology flow chart

The methodology involves seven primary stages. The first stage is conducting a literature review on cartographic design principles for web maps and examining web mapping products that aid travel-related decisions. In the second stage, the general concept of the web application and user personas are defined. The third stage entails defining decision-relevant information, including decision-relevant map layers, places, and weather information. The subsequent stage is the implementation phase, which comprises data collection using selected tools and techniques, evaluating and developing ArcGIS APIs,

and visualizing the decision-relevant map layers for the decision support system. After implementation, the web application is evaluated in the next stage, which includes a user study employing evaluation methods such as thinking aloud, questionnaires, and expert interviews, and analyzing the results. Since the design of the web application is user-centered, it is an iterative design process, and the implementation phase can be continued until the evaluation results are satisfactory.

3.1.1 Defining users

To develop a product that caters to a diverse audience, it is essential to design it for specific user groups with special needs. The first step is to select the appropriate individuals for whom the product is intended. Their needs can best represent the needs of a broader set of users. Next, it is crucial to prioritize these individuals while ensuring that the needs of secondary users are not ignored (Cooper et al., 2007). User personas are a valuable tool for communicating the needs of different user types. They help determine which users are the most significant in the design process. User personas are not representations of individual persons but models created from observations of real people. Therefore, based on the startup's information and requirements analysis, assumptions were made about the goals, needs, and travel behavior of four types of primary user personas, as shown in the Table 1. The user persona descriptions are essential for defining the decision-relevant information, determining which prototype features should be developed, and what needs to be visualized. Additionally, potential participants in the user study will be asked to imagine the roles of these two user personas while considering their travel scenarios outlined in Table 1.

Table 1 user cases

	PERSON-A	PERSON-B	PERSON-C	TOURISAM AUTHORITY
What	Searches for a long hiking trail for a great exercise including other activities in the hiking trails	Looking for a hiking with fun, maybe less exercise	Looking for a good hiking also with beautiful views	Looking for major hotspot potential to develop more some infrastructure and generate more revenue
When	Trip is fixed to 4 days at the mid of August (Chooses the region to hike based on best months/seasons)	Flexible to go anytime (do not care about time and weather)	Trip is flexible and depends on the weather next week (Chooses day with the best weather on the next week)	Depends on type of activity within the administrative region
Where	Somewhere in Europe	Near the Salzburg Municipal area	Somewhere in Salzburg or Bavaria	Many states administration
Other Details	Needs overnight stays and places to eat along the trails	Want to take his own bear/drinks and make a picnic.	Wants to have lunch at a restaurant near a nice viewpoint, and the other exercise	depending on the footfall, will develop some infrastructure (café/restaurant, benches, light source etc...)

3.1.2 Defining Specific Information

After considering the assumptions made about the two primary user personas and the general concept of the web application, decision-relevant information was classified into three primary groups:

- Information on map layers
- Information on places information
- Additional in information

Information on map layers

The web mapping application needs to have different map options for different users, depending on their needs. There are two types of map layers: basemaps and map overlays. Basemaps are the main background maps and include a customized general-purpose basemap, a terrain basemap, and a satellite basemap. The customized general-purpose basemap provides a neutral, simple map with basic features and highlights the system's recommendations. The terrain basemap shows the landscape, including elevation, and has labels and roads. The satellite basemap shows high-resolution satellite imagery with labels.

Map overlays can be added on top of any basemap and provide additional information. Users can apply multiple overlays at once. The decision-relevant overlays include country boundaries and subdivisions, which are important for showing the system's recommendations, and weather overlays, which display real-time or historical weather data. These overlays help users make decisions about planning their trips.

Table 2 Information on map layers

Category	Type	Details
Basemaps	Customized basemap	A neutral background basemap with minimal colors, labels, and features, and hill shading. It provides global coverage and serves as the primary basemap to provide geographic context while highlighting the system's recommendations.
	Terrain	A topographic map with contour lines and elevation, including labels and roads across the globe.
	Satellite	Displays high-resolution satellite imagery that includes labels and provides global coverage.
Map overlays	Countries' boundaries and country subdivision	Displays the geometry of boundaries with additional properties, such as the names of countries, to visualize the system's recommendations.
	Weather overlays	Provides users with real-time satellite temperature or precipitation weather data, historical weather data, or forecast weather over any basemap to support the decision-making process of planning trips on particular days. The weather overlays include forecast weather overlay (temperature and precipitation), current weather overlay (temperature and precipitation), and historical weather data overlay.

Information on places

The information on places category in the web mapping application provides users with information about various objects of interest that may influence their travel decisions. This information is organized into seven categories based on the needs of the user personas, including accommodation, food and drink, local facilities, health, transport, tourism, and hiking. Each category contains detailed information about the objects within it, such as hotel ratings, restaurant menus, public transportation schedules, and tourist attractions, to help users make informed decisions.

Table 3 Information on places

Category	Objects	Details
Accommodation	Hotels, hostels, guest houses, motels, etc.	Name, location, address, opening hours, contact, website's link, rating, photo
Food and drink	Cafes, restaurants, bars, grocery stores, etc.	Name, location, address, opening hours, contact, website's link, rating, photo
Local facilities	Supermarkets, outdoor and sport shops, kiosks, parking lots, camping grounds, public toilets, public water fountains, ATMs, etc.	Name, location, address, contact, opening hours, website's link
Health	Ambulance stations, pharmacies, emergency rooms, etc.	Name, location, address, contact, opening hours, website's link
Transport	Train stations, bus stops, aerial ways, etc.	Name, location, address
Tourism	Tourist attractions (viewpoints, museums, galleries, castles, churches, monasteries, ruins, etc.), leisure facilities (playgrounds, swimming areas, parks, gardens, etc.)	Name, location, address, opening hours, contact, website's link, rating, photo
Hiking	Hiking trails	Location, route type, surface, elevation gain, length, difficulty, duration, rating

Additional information

Additional Information is based on the specific information about each category of the places. In depth is mainly based on the detailed information, such as, size of the parking space and its access ticket, Bus routes for the specific bus stops and ticket accessibility, about the hotels and restaurants and booking, about the hiking trails and so on. This information is organised in the pop-ups.

3.2 Study Area selection

For the research purpose the Nockstein Mountain is chosen because of this range provides easy accessibility and associability with variety of touristic hotspot and further range for the extension for further studies. Nockstein, situated in the scenic region of Koppl, Austria, offers a splendid opportunity for hiking enthusiasts to immerse themselves in the natural beauty of the area. The mountain presents a moderate-level hiking trail that combines both serenity and adventure. The Figure 11 below is showing Location of the study area.



Figure 11 Location of the study area

When you go on the Nockstein hike, you'll be surrounded by beautiful green landscapes, including dense forests that create a magical atmosphere. The trail goes through these captivating forests, giving you a chance to enjoy the peace and see all the different plants and animals that live in this untouched environment. As you climb higher, the path becomes rocky, which adds some excitement to the journey. Although these parts require careful attention and footing, reaching the top feels like a great accomplishment.

It's important to protect the environment while hiking, so hikers are encouraged to follow the principles of Leave No Trace. This means preserving the natural beauty of the area by being respectful of the surroundings and other hikers. By doing this, visitors help maintain the pristine ecosystem of Nockstein for future generations. (GmbH, n.d.)

In conclusion, embarking on the Nockstein hike in Koppl, Austria, promises a memorable outdoor experience amidst breathtaking natural landscapes. From the verdant forests to the rocky slopes and the captivating panoramic views, the journey encapsulates the beauty and allure of this remarkable region.

The Nockstein is mainly the starting point for all hikes which is located in the centre of Koppel. The average walking and hiking time is on average of 1.3 hrs, height difference: 300 m.

Moderate hike with beautiful view.

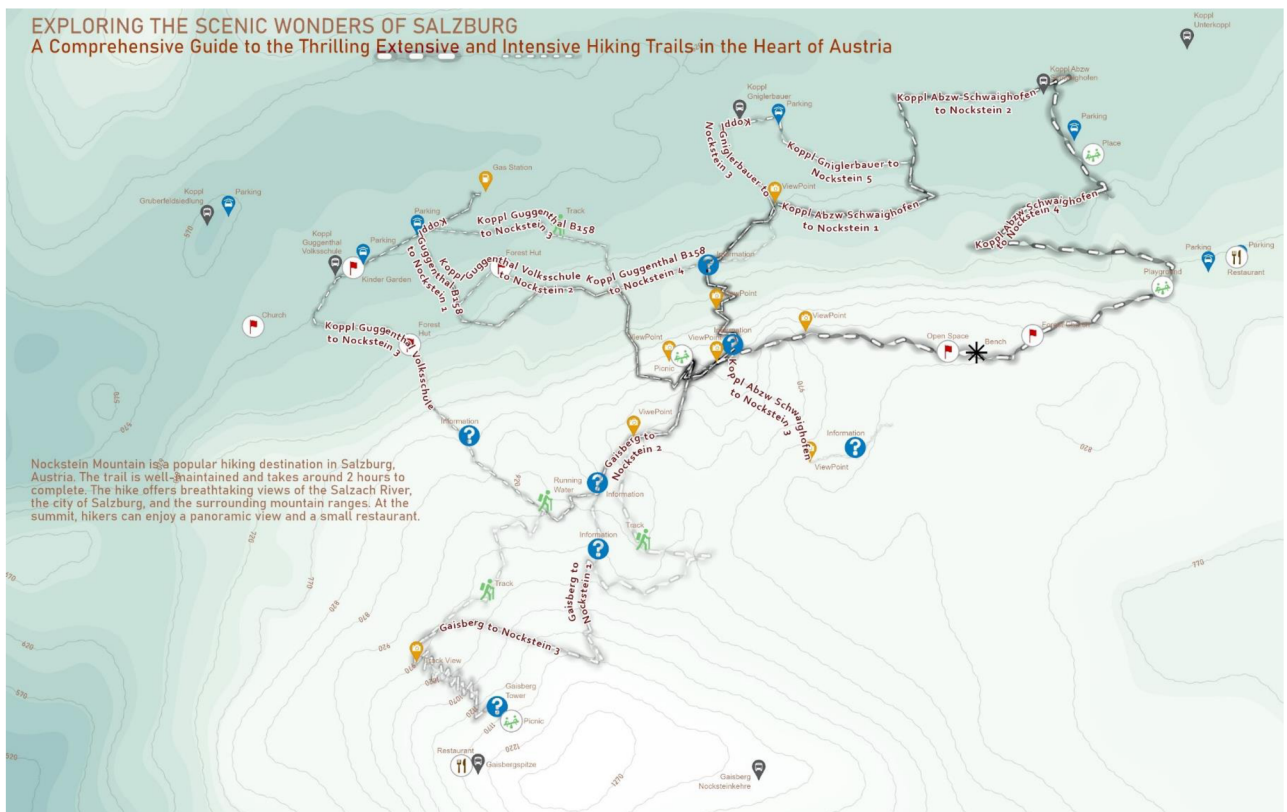


Figure 12 Distribution of Hiking trails @Ravi PANDEY

3.3 Data Collection

In order to create a web mapping application that displays decision-relevant map layers, we need to gather the information that was defined in Figure 13 Data collection process. This section explains the methods and tools that were used to collect the necessary data.

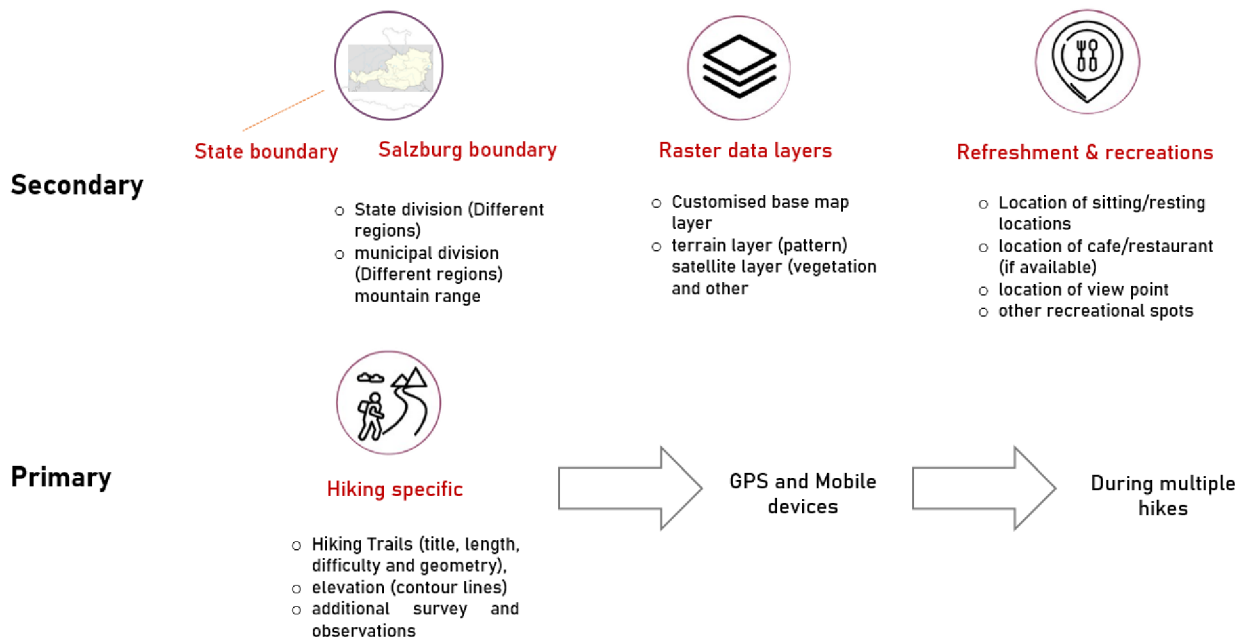


Figure 13 Data collection process

(Salzburg, ALS Befliegungen, n.d.)

(Salzburg, Airborne Laserscanning (ALS) Download, n.d.)

3.4 Selection of APIs

ArcGIS API is an excellent choice for developers because it offers a wide range of customization options and advanced features. With this API, developers have the freedom to customize maps according to their specific needs, ensuring a unique and tailored look and feel. The API supports advanced functionalities like geocoding (converting addresses to coordinates), routing (finding the best path between locations), and 3D visualization, which are essential for professional and enterprise applications.

What sets ArcGIS API apart is its global coverage, providing accurate and comprehensive location-based services worldwide. This makes it reliable for applications that require precise and reliable mapping data. Additionally, ArcGIS API allows for offline maps, enabling users to access maps and data even without an internet connection, which can be crucial for outdoor activities in remote areas or areas with limited connectivity.

Overall, ArcGIS API offers a robust and flexible mapping solution with its extensive customization options, advanced geospatial analysis capabilities, global coverage, and offline map availability. It is a powerful tool for developers seeking to create professional-grade applications that require accurate mapping, advanced features, and a high level of customization. The api selection criteria is represented in Table 4 below.

Table 4 API Selection criteria

CRITERIA	GOOGLE MAPS API	OPENSTREETMAP API	MAPBOX API	ARCGIS API
Global coverage	Excellent	Varies depending on collective mapping	Good	Excellent
Accuracy	Excellent	More accurate than Mapbox in some cases	Can be inferior depending on region	Excellent
Customization options	Limited	Flexible but requires third-party services for unique customization	Highly customizable with unique customization options	Highly customizable with extensive customization options
Overlays	Supports images and basic shapes such as polyline, polygon, circle, etc.	Supports images and basic shapes such as polyline, polygon, circle, etc. Additional use of Overlay API for vectors and pointers on slippy maps	Supports images and basic shapes such as polyline, polygon, circle, etc.	Supports images and basic shapes, and additional overlays can be added via the GraphicsLayer and FeatureLayer APIs
Map layers	Terrain, satellite, traffic, transit, and bicycle layers	Streets, terrain, traffic, satellite, boundaries layers	Streets, terrain, traffic, satellite, boundaries layers	Offers a wide range of layers, including basemaps, imagery, terrain, and more. Custom layers can also be created and added to maps.
Offline maps	No offline mode available via API	Can be downloaded and used entirely offline	Offline functionality	Supports offline maps via mobile apps or the Runtime SDK, which allows users to download maps and data for use when offline
Complexity of code	Less complex code, well organized examples	Longest code, but in combination with Leaflet API, it becomes less complex	More complex architecture, standardization, and data flow	Can be complex due to the wide range of functionality and customization options available
Usage limitations	No strict limitations	Limitations for heavy usage	No strict limitations	No strict limitations
Cost and pricing	Costs per requests	Open source, free	Costs per usage	Offers a range of pricing options, including a free developer account and paid plans based on usage and features

3.5 Technical engagements

For the overall thesis task, the distribution and engagement of tools can be categorized as follows:

1. Data Compilation and Processing

- Esri ArcGIS Pro: Used for spatial data analysis, geoprocessing, and creating maps.
- GPS Visualizer: Utilized for visualizing GPS data and converting it into various formats.
- Alltrails: Employed for data compilation and processing, particularly for rail-related data.

2. Layer Hosting and Building:

- ArcGIS Developer Account: Used for hosting and managing spatial layers and services.
- CodePen: Employed for building and testing interactive web-based visualizations and prototypes.
- Visual Studio Code (VSCode): Utilized as an integrated development environment (IDE) for coding and building applications.

3. Server Hosting and Publishing:

- GitHub: Used for version control and collaboration, hosting code repositories, and managing project workflows.
- Netlify: Employed for web hosting and deploying static websites or applications.
- Hostinger: Utilized for server hosting and publishing websites or web applications.

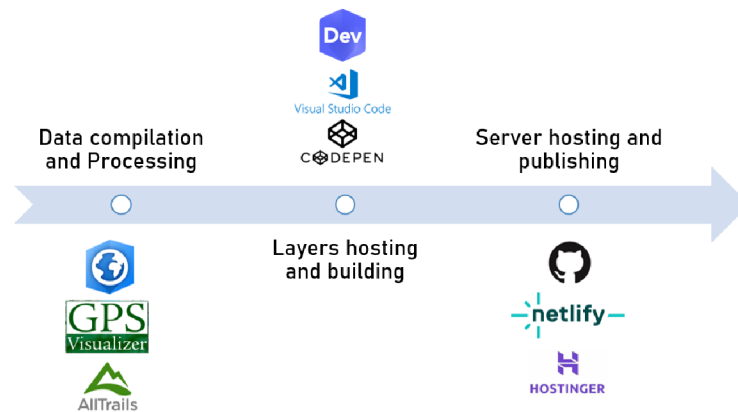


Figure 14 Distribution and Engagement of tools for the overall task

These tools are distributed and engaged in the overall thesis task to facilitate various aspects of data compilation, processing, analysis, visualization, and publication. Esri ArcGIS Pro, GPS Visualizer, and Alltrails are primarily used for data compilation and processing tasks. ArcGIS Developer Account, CodePen, and VSCode are engaged for layer hosting, building interactive visualizations, and coding. GitHub, Netlify, and Hostinger are utilized for version control, server hosting, and publishing of the final thesis project, the overall process is represented in the above Figure 14.

3.6 Development of the web application

Based on the provided information, the distribution and engagement of the technologies were used for task thesis task is summarized as follows:

- **React:** React is a JavaScript library for building user interfaces. It seems that you utilized React for a majority of your thesis task, as it accounted for 62% of the codebase.
- **Node.js:** Node.js is a runtime environment for executing JavaScript code outside of a web browser. It appears that you used Node.js for backend development or other server-side tasks, with a contribution of 10% to the codebase.
- **Yarn:** Yarn is a package manager for JavaScript. Although not explicitly mentioned how it was used, it is typically employed for managing dependencies and packages in a project.
- **Ruby:** Ruby is a dynamic, object-oriented programming language. It seems that you utilized Ruby for a smaller portion of your thesis task, accounting for 7% of the codebase.
- **ArcGIS API:** ArcGIS API refers to the JavaScript API provided by Esri for working with their ArcGIS platform. It is used for integrating spatial capabilities into web applications. It is not specified how extensively you used this API, but it is one of the technologies employed in your thesis.

Regarding the number of units of the programming languages, following breakdown was developed:

- ✓ **TS (TypeScript)** 16 units: TypeScript is a typed superset of JavaScript that compiles to plain JavaScript. It appears that you used TypeScript in your project, as indicated by the ".ts" file extension. TypeScript enhances JavaScript with static types and additional language features.
- ✓ **SCSS (Sass)** 10 units : SCSS is a preprocessor scripting language that is compiled into CSS. It seems that you utilized SCSS for styling and designing the user interface of your application, accounting for 25% of the codebase.
- ✓ **Others (HTML and .js)** 7 units : In addition to the mentioned technologies, you also used HTML and plain JavaScript (".js") files, which collectively accounted for 5% of the codebase.

Table 5 distribution of programming languages

✓ Language	✓ Number of Units
✓ .ts (62%)	✓ 16
✓ .scss (25%)	✓ 10
✓ Others (HTML and .js)(5%)	✓ 7

3.7 Methods of the User Research

To effectively address the research questions outlined in the objectives, it is essential to select appropriate research methods. This section will discuss various methods that can be employed to conduct a user study. By utilizing these methods, valuable insights can be gathered to inform the research and contribute to the findings.

3.7.1 Questionnaire

In situations where conducting the thinking aloud method is not feasible, an online questionnaire can be a valuable alternative for gathering participants' characteristics, preferences, and insights regarding the proposed design and visualization of the web mapping application for the decision support system.

An online questionnaire offers the advantage of reaching a larger number of participants and collecting data in a structured and efficient manner

3.7.2 Interview

Conducting interviews allows for in-depth exploration of participants' experiences, perspectives, and insights. Structured interviews follow a predetermined set of questions, while semi-structured interviews provide more flexibility for participants to elaborate on their responses. Interviews offer the opportunity to delve deeper into specific topics and gain a comprehensive understanding of user needs and preferences.

3.8 Overall Methodology

The overall methodology is based on achieving two objectives, and for that, it requires specific steps, tasks, tools, and techniques. The first methodology is completely focused on the data acquisition, compilation, and spatial visualization strategy, while the second methodology is more centered around the development, visualization, and evaluation processes delatied described in the Figure 15 Methodology flow chart below.

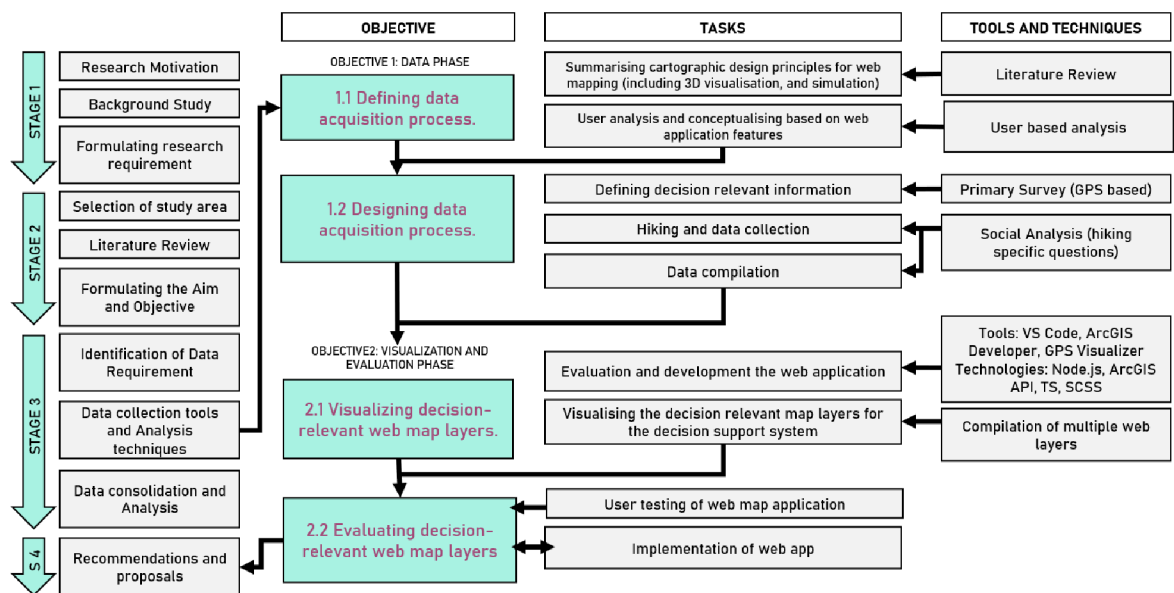


Figure 15 Methodology flow chart

4 IMPLEMENTATION OF THE MAP LAYERS TO SUPPORT HIKE PLANNING

The web application developed, aimed to provide a platform for users to find and plan hiking trails in Salzburg area. This chapter presents the results of the development and testing of the web application.

Firstly, the web application was developed using modern web technologies such as Node.js for the both frontend and backend. The user interface was designed to be simple and intuitive, with clear calls to action and easy navigation. The application features a search bar that allows users to search for hiking trails by name or location. The results are displayed on a map with markers indicating the trailhead location. Users can then click on a marker to view additional information about the trail, including distance, difficulty level, and some additional comments. The application then generates a route and displays it on the map, along with estimated time and distance.

To evaluate the effectiveness of the web application, a usability test was conducted with a group of ten participants. The participants were asked to perform several tasks using the application, including searching for hiking trails, creating a hiking plan, and additional visual criteria of the trails. The participants were also asked to provide feedback on the usability and user experience of the application.

The results of the usability test were positive, with all participants able to complete the tasks with ease. The participants also provided positive feedback on the design and usability of the application, noting its simplicity and intuitiveness. Several participants also commented on the usefulness of the reviews and ratings system, as well as the ability to create and save hiking plans.

Overall, the development and testing of the web application demonstrated its effectiveness in providing users with a user-friendly platform to find and plan hiking trails in their area. The application's intuitive user interface, search functionality, and review system were noted as particularly effective features. Future work could involve expanding the database of hiking trails and incorporating additional features such as weather forecasts and real-time trail conditions.

4.1 Implementation of Prototype

The initial version of the web-based application only includes the interface that the user interacts with. The server-side that provides the required data is not yet developed. To simplify the development process, local data or readily available APIs that are easy to integrate were used.

4.1.1 Datasets and APIs

To visualize the system's recommendations, several datasets were required, including countries boundaries, country subdivision, hiking trails, and places such as hotels and restaurants. After evaluating different APIs, it was decided to use a ArcGIS Maps SDK for JavaScript 4.26 (ArcGIS API).

For visualizing the system's recommendations, GeoJSON datasets were used for countries and Salzburg's administrative areas, obtained from sample code and WGS84 GeoJSON format, respectively. Basemaps were customized using the Google Maps JavaScript API, which offers basic map types like satellite and terrain. Hiking trails data was collected using two methods of Outdooractive API, providing title, difficulty, length, elevation, etc.. Only datasets of restaurants and hotels were downloaded and pre-uploaded in JSON format using the Public Overpass API instances to obtain decision-relevant information like coordinates, name, address, and a website link.

Basemaps

The Google Maps JavaScript API was used to customize a map with its own content. The API features basic map types such as satellite and terrain, which were added to the prototype.

Hiking trails

while the "ArcGIS API method sends detailed information about several hikes. Thus, the following hiking trail data was collected within the Koppl Range: title, difficulty, length, elevation, and geometry.

Places

For the prototype purposes, only the datasets of restaurants and hotels were downloaded to visualize decision-relevant information in the form of point objects. These datasets were pre-uploaded in JSON format using Public Overpass API instances since the Public Overpass API has low performance. The following data were obtained within the Koppl Range: coordinates, name, address, and a website link.

4.1.2 Client-Side User Interface

TypeScript Libraries Used in the Prototype

The prototype used several TypeScript libraries to make it work properly. These libraries helped in implementing different features and functionalities. For example, the Material UI library was used to create UI elements such as the search bar, filter menu, layer menu, and icons, while the Google-map-react library was used to display the map and markers on it.

The "Supercluster" library was also used to cluster nearby hiking trails to make it easier for users to view and navigate them. These libraries helped in creating a user-friendly prototype that can be easily understood and navigated by users. All in all, these libraries played a crucial role in making the prototype functional and useful for its intended purpose.

UI Elements

This web application for hiking allows users to search and discover hiking trails near their location. The UI (User Interface) of the website is designed to be simple, intuitive, and easy to navigate, making it user-friendly for both experienced hikers and beginners. Here are some of the UI elements of the hike application:

- ✓ **Header:** The header of the website contains the title of the trail unit(s).
- ✓ **Navigation Bar:** Below the header, there is a navigation bar that contains links to different sections of the website, including Home, Trails, About, and Contact.
- ✓ **Trail Cards:** The main section of the website displays a grid of trail cards, each representing a different hiking trail. The trail cards contain information such as trail name, location, difficulty level, distance and other specifications. Users can click on a trail to view more details about the trail.
- ✓ **Filters:** On the left-hand side of the trail cards, there are filters that allow users to refine their search based on difficulty level, distance, rating, and features such as dog-friendly or wheelchair accessible.
- ✓ **Trail Details:** When a user clicks on a trail card, they are taken to a new page that displays more information about the trail, including a map, trail description, photos, and reviews.
- ✓ **Back Button:** On the trail details page, there is a back button that allows the user to easily navigate back to the previous page.
- ✓ **Added Values:** It contains links to web-app collaborations, as well as a copyright notice and disclaimer.

Overall, the UI elements of webapplication are designed to provide a seamless and enjoyable user experience for hikers looking to discover new trails. The website is easy to navigate, and the trail cards and filters make it simple to find a trail that fits the user's preferences.

The loading page of the for the application is describing about basic information about the hiking is Salzburg, Austria, Shown in the Figure 16. The Loading page is containing information about the Specific hiking trails in Salzburg, and how to reach there along with the connectivity information. The credits from the developer side and button for going to the main map view is given.

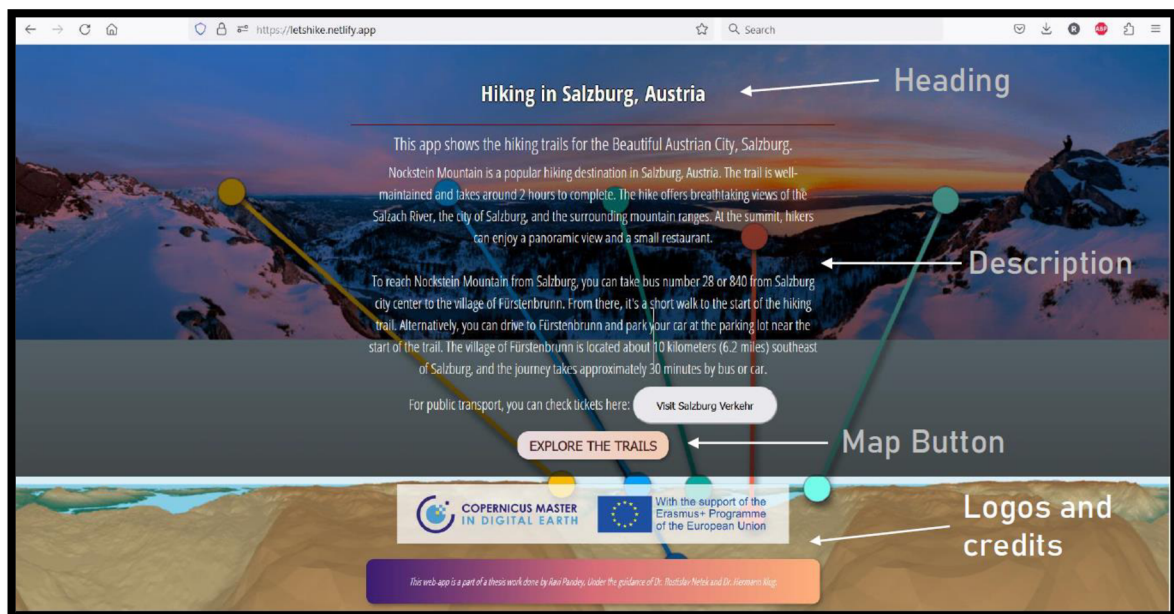


Figure 16 UI Elements and prototyping for the loading page.

After accessing the map view, the hiking trails for the specific case study area are visible through the UI elements, and the prototyping for the map page is shown in Figure 17. This page features a 3D map layout displaying the distribution of specific hiking trails. Additionally, there are points on the map with pop-ups providing information about the hiking trails. The page also includes a list of trails and respective filters, with various widgets and buttons arranged within the menu panel.

The provided code defines a class called `MenuPanel` and exports it as the default export. Here's a summary of the code:

The `MenuPanel` class has two properties: `state` and `container`. The `state` property is assigned the value of the `state` parameter passed to the constructor, and the `container` property is assigned a reference to the DOM element with the class "menuPanel".

Inside the constructor, several instances of other classes are created:

- `SelectionPanel`: An instance of the `SelectionPanel` class is created, passing the `trails` and `state` objects as parameters.
- `DetailPanel`: An instance of the `DetailPanel` class is created, also passing the `trails` and `state` objects as parameters.
- `BasemapPanel`: An instance of the `BasemapPanel` class is created, passing the `state` object as a parameter.

These instances are stored in the `panels` object, with keys representing the panel names and values representing the corresponding panel instances.

Overall, the `MenuPanel` class serves as a container for different panels (such as `SelectionPanel`, `DetailPanel`, and `BasemapPanel`) and allows access to the state object. It facilitates the initialization and management of these panels within the menu panel container. The specific typescript part is mentioned below.

```
export default class MenuPanel {  
  
  state: State;  
  container: HTMLElement;  
  
  constructor(state: State) {  
  
    const trails = state.trails;  
    this.state = state;  
    this.container = <HTMLElement> document.querySelector(".menuPanel");  
  
    const selectionPanel = new SelectionPanel(trails, state);  
    const detailPanel = new DetailPanel(trails, state);  
    const basemapPanel = new BasemapPanel(state);  
  
    const panels = {  
      selectionPanel,  
      detailPanel,  
      basemapPanel  
    };  
  }  
};
```

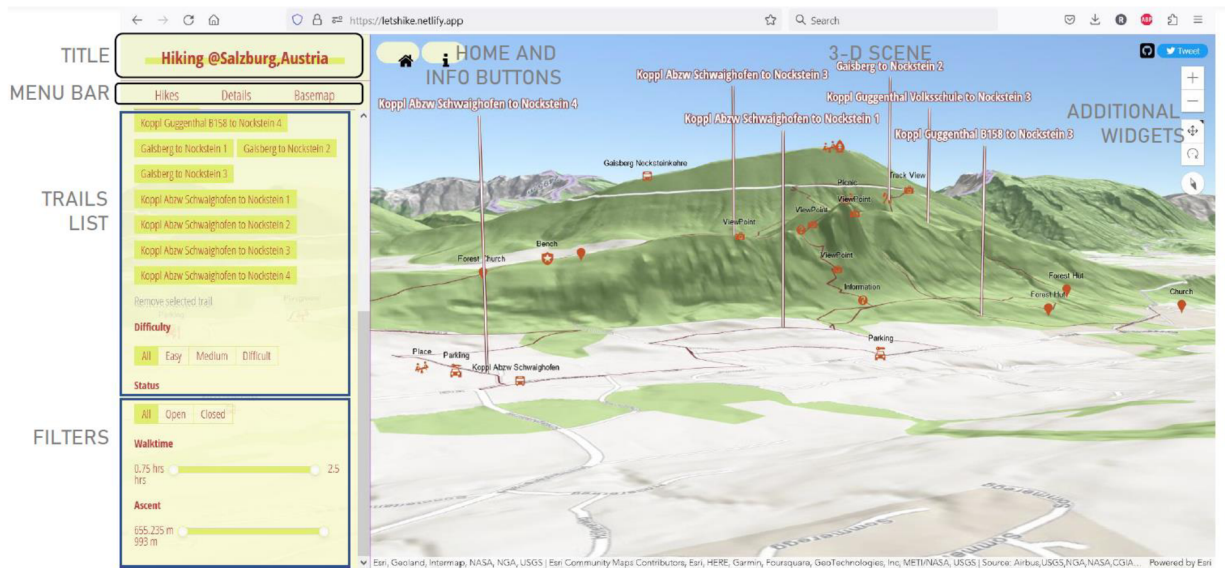


Figure 17 UI Elements and prototyping for the map page.

The trails were organized and managed on the ArcGIS Developer account, and an additional web scene was used as the background. The TypeScript code provided below allows access to various trail information and facilitates its management.

```

export default {
  scene: {
    websceneItemId: "fbcf15a280544502a0390be05d9c9dde"
  },
  data: {
    trailsServiceUrl:
    "https://services.arcgis.com/elpS810f3WpYRd0K/arcgis/rest/services/trails/FeatureServer/0"
  },
  trailAttributes: {
    name: "Name",
    id: "RouteId",
    difficulty: "Difficulty",
    walktime: "Hiketime",
    status: "Access",
    ascent: "Ascent",
    description: "Description"
  },
  filterOptions: {
    singleChoice: ["difficulty", "status"], // have string values
    range: ["walktime", "ascent"] // have numeric values
  },
  colors: {
    defaultTrail: "#7a2d2d",
    selectedTrail: "#f9a352"
  }
};

```

After selecting any hiking trail or path, either from the list or the map view, the zoomed and highlighted trails become visible. You can see detailed information about the trail, including its difficulty level and other specifications. Additionally, there is an animation-based elevation profile graph that displays the trail's elevation changes. Alongside the

graph, you can view trail statistics such as distance, duration, and elevation gain, which is shown with the Figure 18, below.

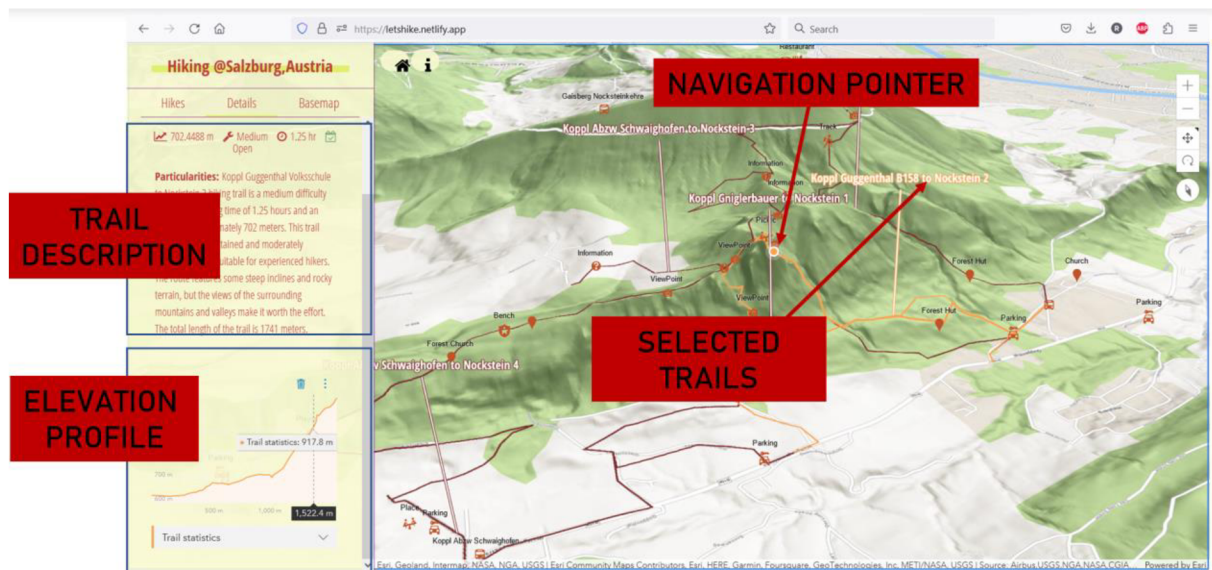


Figure 18 selected trail

The provided code snippet is written in TypeScript and includes two private methods: `generateTrailsPanel()` and `generateFilterPanel()`.

The `generateTrailsPanel()` method creates a trails panel by iterating over an array of trails. For each trail, it creates a `<div>` element with various data attributes based on the trail's properties. Event listeners are attached to the trail elements, triggering a callback function that sets the selected trail in the state object when a trail element is clicked. The `generateFilterPanel()` method generates filter panels, but the implementation details of the `generateSingleChoiceFilters()` and `generateRangeFilters()` methods are not provided.

Overall, these methods are likely part of a larger component responsible for rendering a user interface that displays trails and filter options.

```
private generateTrailsPanel(): void {
  const state = this.state;

  this.trails.forEach((trail) => {
    const trailElement = domConstruct.create("div", {
      "innerHTML": trail.name,
      "data-difficulty": trail.difficulty,
      "data-id": trail.id,
      "data-category": trail.category,
      "data-walktime": trail.walktime,
      "data-status": trail.status,
      "data-ascent": trail.ascent,
      "class": "trail"
    }, this.trailsPanel);

    on(trailElement, "click", (evt) => {
      state.setSelectedTrail(parseInt(evt.target.dataset.id, 10));
    });
  });
};
```

```

}

private generateFilterPanel(): void {
  this.generateSingleChoiceFilters();
  this.generateRangeFilters();
}

```

Definitely, there is an option to change the basemap based on convenience and explore more information through pop-ups. This feature is visualized in the interface, allowing users to switch between different basemaps according to their preference. Additionally, the pop-ups provide additional information and details when interacted with, enhancing the user's exploration experience Figure 19.

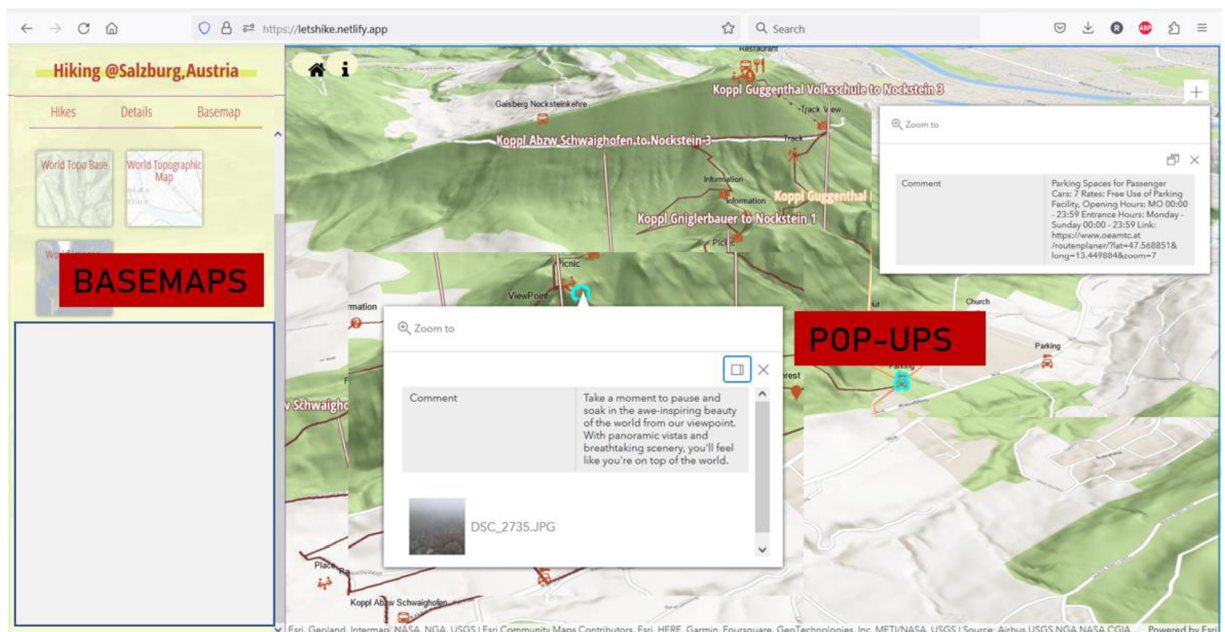


Figure 19 Basemap and pop-ups.

The BasemapPanel class has two properties: container and basemapContainer, which are assigned to the DOM elements with the IDs "basemapPanel" and "basemaps" respectively.

The constructor function takes a state object as a parameter. Inside the constructor, an event listener is attached to the loaded property of the map object in the state.view. This event listener is triggered when the map finishes loading.

Within the event listener, the code filters the map layers to find a group layer with the title "Basemap". It then iterates over the layers within the basemap group layer.

For each layer, a <div> element representing a basemap item is created using domConstruct.create(). The created div element has a class of "basemapItem" and its background is set to the thumbnail URL obtained from the portalItem associated with the layer. The layer's ID and title are also set as data attributes and inner HTML of the div element respectively.

An event listener is attached to each basemap item, listening for click events. When a basemap item is clicked, the callback function sets the currentBasemapId property of the state object to the clicked basemap item's ID.


```

export default class BasemapPanel {

  container: any;
  basemapContainer: any;
  constructor(state: State) {
    this.container = dom.byId("basemapPanel");
    this.basemapContainer = document.querySelector(".basemaps");
    state.view.map.watch("loaded", (value) => {
      if (value) {
        const basemapGroup = <GroupLayer> state.view.map.layers.filter((layer) => {
          return (layer.title === "Basemap");
        }).getItemAt(0);
        basemapGroup.layers.forEach((layer) => {
          // get access to portalItem property
          const portalLayer = <GroupLayer> layer;
          portalLayer.portalItem.watch("loaded", (value) => {
            if (value) {
              const basemapItem = domConstruct.create("div", {
                class: "basemapItem",
                style: `background: url(${portalLayer.portalItem.getThumbnailUrl()}) no-repeat center`,
                "data-id": layer.id,
                innerHTML: `<div>${layer.title}</div>`
              }, this.basemapContainer);

              on(basemapItem, "click", (evt) => {
                state.currentBasemapId = evt.target.dataset.id;
              });
            }
          });
        });
      }
    });
  }
}

```

In summary, the provided section introduces an application focused on hiking trails in Salzburg, Austria. The loading page Figure 16, provides basic information about the specific hiking trails, including directions and connectivity details. From there, users can proceed to the map view Figure 17, which features a 3D map layout displaying the distribution of hiking trails. The map includes pop-ups with trail information and a list of trails with filters. When a trail is selected, it becomes highlighted and zoomed in, revealing detailed information such as difficulty level and an elevation profile graph Figure 18, displaying changes in elevation. The application also allows users to switch basemaps and explore additional information through pop-ups.

Overall Visual Variables

The application you're describing focuses on cartographic visual variables and incorporates various essential cartographic elements. These elements are fundamental components used in map design to effectively convey geographic information. Here are some key cartographic elements that could be included in your application:

- **Layout and Structure:** It includes a clear map title to convey the map's purpose, a comprehensive legend to interpret symbols and colors, and an elevation profile to accurately estimate distances. A north arrow ensures proper orientation, while

grid lines establish a coordinate system for precise location referencing. The use of symbols, icons, colors, and patterns enhances visual representation and aids in understanding different map features and thematic data. Labels provide textual information, while insets offer supplementary detail or focus on specific place of interest (as pop-ups). Few basemaps serves as the foundational background, providing context for the thematic information overlaid on top. By incorporating these cartographic elements, the application facilitates intuitive and informative map exploration, enabling users to interpret geographic data effectively.

- **Color Scheme:** Using a dark brown color for representing the overall hiking trails and a lighter color for highlighting selected trails can be an effective choice for conveying information and enhancing the user experience. Brown colors are often associated with earthiness, nature, and outdoor environments, which aligns well with the theme of hiking trails. Dark brown can create a sense of depth and solidity, giving the trails a grounded and organic feel. This color choice helps users distinguish the trails from other elements on the screen, making them visually prominent. By using a lighter color to highlight selected trails, you create a visual contrast that draws attention to the user's chosen options. This highlighting effect helps users easily identify and track their selections, providing a clear visual indication of the trails they have chosen. Using brown colors for icons in pop-ups maintains consistency with the overall theme and ensures a cohesive design. It reinforces the connection between the pop-ups and the trails, as the icons are directly related to the hiking experience.

Overall, the use of dark and light brown colors, along with the highlighting effect and consistent iconography, can create a visually appealing and functional interface for your hiking trail application.

- **Typography:** Using sans serif fonts for various text elements in your application, such as headings, subheadings, lists, filters, pop-ups, and other texts, can contribute to readability and establish a consistent visual hierarchy. Sans serif fonts are known for their clean and modern look, making them suitable for digital interfaces. Here's how different font sizes and styles can be used effectively:
 - a. **Headings:** Choosing a larger font size and a bold or semi-bold style for headings helps them stand out and grab attention. Headings typically introduce sections or important information, so a distinct and larger font size can create visual hierarchy and make them easily scannable.
 - b. **Subheadings:** Subheadings often provide additional context or organize content within sections. Using a slightly smaller font size than headings, and perhaps a regular or medium weight, helps differentiate them while maintaining readability.
 - c. **Lists:** Lists can benefit from a slightly smaller font size compared to headings and subheadings. This ensures that the text is legible

and doesn't overwhelm the user. Using a regular or light font weight can maintain readability while still distinguishing the list items.

- d. Filters: If filters are displayed prominently on the interface, you may want to consider making them stand out using a larger font size and a slightly bolder style. This makes it easier for users to locate and interact with the filters.
- e. Pop-ups: Pop-ups typically contain important information or require user attention. Using a larger font size ensures readability, and using a bold or semi-bold style can help emphasize key points within the pop-up content.

By using sans serif fonts consistently across different text elements, you maintain a cohesive visual style throughout the application. However, remember to ensure appropriate contrast between the font color and the background to optimize readability, especially for smaller font sizes. Conducting usability tests and gathering feedback from users can help fine-tune the font choices and sizes to ensure the best readability and user experience.

- **Icons and Images:** Using relatable icons for hiking-related points in your application can enhance the user experience and provide visual cues that quickly convey information. Incorporating icons from Esri's developer interface, which offers a wide range of icons specifically designed for mapping and geospatial applications, can be beneficial. Here's how icons can be used effectively:

- a. Hiking Points: Assigning icons that represent different hiking-related points, such as trailheads, scenic viewpoints, campsites, or landmarks, helps users identify and understand the nature of each point at a glance. For example, using a hiking boot icon for trailheads, a mountain icon for viewpoints, or a tent icon for campsites.
- b. Information and Links: If the icons are accompanied by additional information or links about the place, you can leverage Esri's icons to incorporate visual indicators or overlays that denote the availability of such details. This can include icons with an "i" symbol for information or a chain link icon for links, placed alongside the primary icons.
- c. Consistency: To maintain a cohesive visual language, ensure that the style, size, and color scheme of the icons align with the overall design of your application. Consistency in icon design helps users quickly recognize and associate specific symbols with relevant hiking points.
- d. User-Friendly Design: When using icons, it's important to consider the usability aspect. Ensure that the icons are intuitive and easily understood by your target users. Conducting user testing or gathering feedback can help identify any potential confusion or ambiguity in icon meanings.

By leveraging Esri's developer interface icons and aligning them with the specific hiking-related points in your application, you provide users with visual cues that make it easier to navigate and explore hiking trails and related information.

- **Spacing and Alignment:** Consistent spacing and alignment are crucial for creating a visually pleasing and well-organized layout in the hiking application. Here are some key considerations performed:

a) Spacing between Elements:

- Margins: Providing consistent margins around elements, such as buttons, images, text blocks, and containers, helps create a sense of balance and separation between different components. It allows each element to breathe and avoids a cluttered appearance.
- Padding: Applying consistent padding within elements, such as containers or cards, ensures that the content is visually separated from the edges, enhancing readability and visual clarity.

b) Alignment of Text and Elements:

- Text Alignment: Maintain a consistent text alignment, such as left-aligned or centered, throughout the application. This provides a sense of order and makes it easier for users to scan and read the content.
- Visual Hierarchy: Aligning elements based on their importance and hierarchy can guide users' attention. For example, left-aligning headings and subheadings while keeping body text justified can help differentiate between different levels of information.
- Grid-based Layout: Employing a grid system for UI layout can help ensure consistent alignment of elements. Grids provide a framework for organizing content, aligning elements to specific columns or rows, and maintaining a structured appearance.

c) Visual Consistency:

- Maintain a consistent spacing rhythm throughout the application. For example, using the same spacing units between different elements creates a harmonious visual flow.
- Ensure that the alignment of elements is consistent across different screen sizes and resolutions. Responsive design principles can help achieve this by adjusting spacing and alignment dynamically based on the device's viewport.

By paying attention to spacing and alignment, creation of more visually pleasing and organized layout was done that improves the overall user experience. Consistency in these aspects fosters a sense of professionalism, clarity, and ease of use for the application's interface.

- **Visual Effects:** Visual effects can greatly enhance the user experience in your application by providing visual feedback and making interactions more engaging. Here are some examples of how you can apply visual effects to different elements:

- a) The home button can be made more interactive and noticeable by applying visual effects. For instance, you can add a hover effect that changes the button's color or animates it slightly when the user hovers over it. Additionally, when the user clicks on the home button, you can provide visual feedback such as a subtle animation to indicate that the button has been activated. Additionally it works when a user deselects a trail. This effect helps users understand the current state of the selected trails and provides a clear indication of their actions.
- b) Widgets that include a north scene can benefit from visual effects as well. Consider adding a rotation animation to dynamically update the north scene based on the user's map navigation. This interactive visual effect adds a layer of engagement and helps users orient themselves more easily.
- c) Pop-ups containing information about specific locations can be highlighted using visual effects. By changing the background color, adding borders or shadows, or using a different font color, you can make the selected pop-up stand out from the rest. These visual cues draw attention to the relevant information and ensure users can focus on the content they are interested in.
- d) The elevation profile graph can be made more interactive and visually appealing with visual effects. Smooth transitions can be added through animation when adjusting the range or zoom level of the graph. Additionally, interactive elements like hover effects or tooltips can provide more detailed information when users interact with specific points on the graph.

When implementing visual effects, it's important to strike a balance and use them judiciously. They should enhance the user experience without overwhelming or distracting users. It's beneficial to conduct usability tests and gather feedback to ensure that the visual effects in hike application are effective and well-received by users.

- **Responsive Design:** The web application should be designed to adapt and provide a consistent experience across different devices and screen sizes, ensuring usability most suitable on desktop or any landscape screens.

The next section 4.2, will focus on user evaluation of the application.

4.2 Evaluation of Prototype

For the evaluation a survey was conducted that people take online. The survey is based on pictures of a prototype, which is a rough draft of a product that is not fully functional yet. Participants are asked to pretend they are using the product as one of four different types of users.

The survey is divided into three sections to gather feedback and insights from users about a web mapping application. The first section, titled "General Questions," aims to gather basic details and understand the user's web mapping preferences. It includes inquiries about the user's name, age, location, web mapping experience, and their preferred activities or interests related to web mapping. This section provides a foundation for understanding the user's background and preferences.

The second section, "Visual Expressions and Evaluation," focuses on gathering feedback regarding the interface, map contents, navigation, and accessibility of the web application. Users are asked to evaluate the overall design, aesthetics, and usability of the user interface. They are also prompted to provide insights into the usefulness and relevance of the map contents, as well as the ease of navigation, including zooming, panning, and search functionalities. Additionally, the section seeks feedback on the accessibility features of the web application, such as text size options, color contrast, and compatibility with screen readers. By exploring these aspects, the survey aims to gain a comprehensive understanding of the user's visual experiences and evaluate the effectiveness of the web mapping application.

The final section, "Feedback and Suggestions," allows users to express their thoughts freely and provide additional comments and suggestions about the web application. This section offers flexibility for users to share their impressions, highlight any issues or areas for improvement, and suggest new features or enhancements they would like to see in the app. By providing an open-ended space for feedback, the survey encourages users to provide valuable insights that may not have been covered in the previous sections. This section helps capture the user's overall perspective and provides an opportunity to address specific concerns or incorporate innovative ideas into the web mapping application.

By structuring the survey into these three sections, it aims to gather comprehensive feedback from users, covering their basic details, preferences, visual experiences, and suggestions. This approach ensures that the web mapping application can be better tailored to meet the needs and expectations of its users, resulting in an improved user experience and a more effective web mapping solution.

The survey includes questions with pre-made answers that people choose from, like "pick the best option" or "rate how much you agree." These questions help gather information that is easy to compare and understand.

There are also questions where people can write their own answers in a text box, like "How many difficult trials can you access?" These questions allow people to share their own opinions and experiences, which can help improve the product.

The overall questionnaire was designed into three major sections (questionnaire can be found in the attachments):

- **Section 1: General Questions**
Questions about their basic details and about their web mapping/ activity preferences
- **Section 2: Visual expressions and evaluation**
General questions about the interface, map contents, navigation and accessibility of the web application
- **Section 3: Feedback and suggestions**
Flexibility to write about their comment and additional suggestion about the app.

5 RESULTS AND DISCUSSION

A user study was conducted over a one-week period with the participation of 25 volunteers. Out of the total number of participants, all 25 completed the entire questionnaire, providing valuable feedback that was considered in the analysis. The study was conducted in April-May 2023, and the results will be presented and discussed based on the three major sections of the questionnaire, each focusing on different aspects of the product, including ease of use, features, and overall satisfaction.

The study was conducted over a two-week period, during which participants were asked to provide their opinions on various aspects of the product under evaluation. The participants provided detailed feedback on each section, providing insights into their user experience. The results of the study will be used to improve the product's user interface, functionality, and overall user experience.

5.1 Participant's overview

Out of the 25 responses received, 13 identified as female while 12 identified as male. The gender distribution was relatively balanced, with almost an equal number of male and female participants. This balance was beneficial for the study since participants were asked to imagine the role of the defined user persona, which could be either female or male. Table 6 Table 6 Gender distribution of participant provides a visual representation of the number of female and male participants.

Table 6 Gender distribution of participant

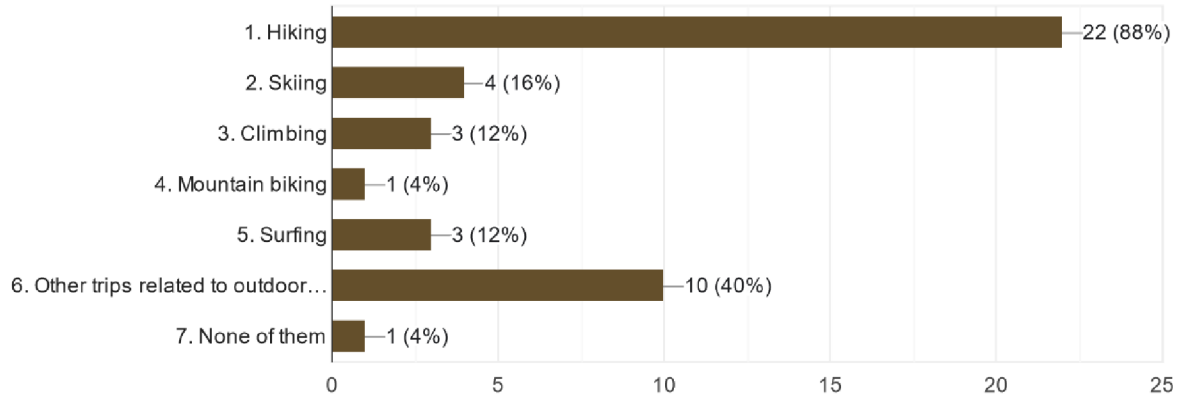
Gender	Number of Participants
Female	13
Male	12

The majority of participants fell in the 18-29 age range, with fewer users in the 30-39 age group. However, to have a more representative sample, it would have been beneficial to have more even age groups, including more participants older than 29. Table 7 provides insights into the age distribution among participating users. Out of the total of 25 respondents, the highest number of participants was in the 18-24 age group, with a smaller number in the 25-29 age group. The age groups of 30-34 and 35-39 had a similar number of participants, and there was one respondent older than 39.

Table 7 Age distribution of participant

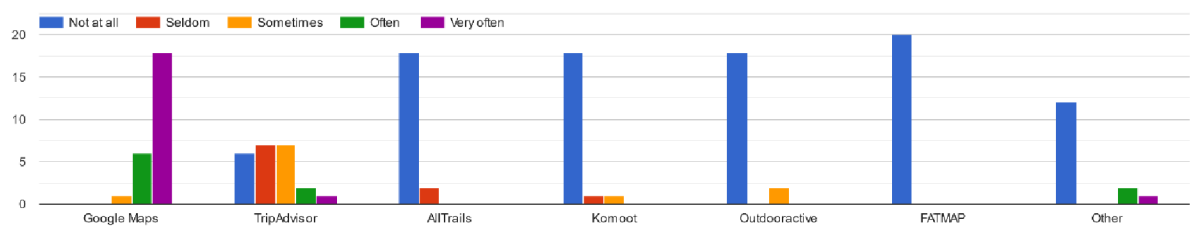
Age Group	Number of Participants
18-24	15
25-29	6
30-34	2
35-39	2
40+	1

Almost all of the 25 participants in the study had previous experience with hiking trips, with nearly half of them also having experience in other outdoor activities (Graph 1). Only one participant had no prior experience with outdoor activities. The fact that the majority of participants had experience with hiking trips was beneficial for the study, as they were better able to imagine the role of the user persona and provide more representative feedback. This experience allowed participants to offer valuable insights into their preferences and needs when it comes to outdoor activity-related products.



Graph 1 distribution of trips conducted

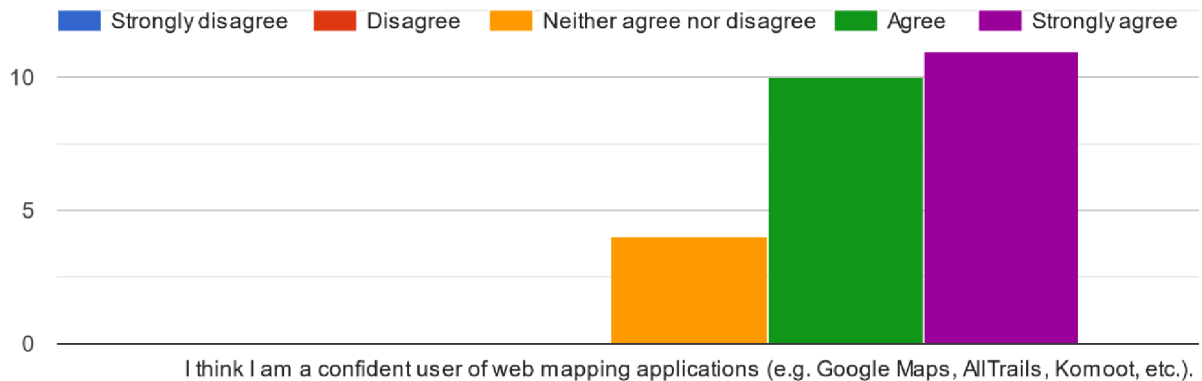
Graph 2 depicts the applications that participants use to plan their outdoor trips and the frequency of their use. Most of the 25 participants reported using Google Maps frequently for trip planning, among other applications. Even the participant who had no prior experience with outdoor activities chose Google Maps as their preferred application. Therefore, it is safe to assume that most participants were accustomed to the interface and functionality of Google Maps, which does not primarily focus on outdoor activities. As a result, some of the proposed design and visualizations might be unfamiliar to participants, despite their experience with outdoor activities.



Graph 2 Distribution of used application for the trips.

Participants were asked about their confidence levels in using web mapping applications such as Google Maps, AllTrails, and Komoot, to obtain information about their prior experience with such applications. For the participant who had no experience with outdoor activities, the question was modified as follows: "Please rate the following statement: I think I am a confident user of web mapping applications (e.g., Google Maps, MAPS.ME, etc.)". As shown in Graph 3, the majority of the 25 participants considered themselves to be confident or very confident users of web mapping applications, indicating their familiarity with basic actions carried out using such applications. However, having more participants who were less or not confident in using web mapping

applications could have provided more diverse insights into the proposed design and visualizations.



Graph 3 user confidence for the web apping applications.

5.2 Participant’s Evaluation

This section is more understanding about the visibility and functionality about the web application. In this section the questions were asked in the way wheather the user is able to understanf the interface and the orking functionality about the application. The questions were organised in various formets, such as optional and short answer type, from basic to advance. All the responds for this evolution section is shown in the Table 8, below

Table 8 Web Application Functionality and User Experience

Question	Positive Response Rate
Can the user load the complete map with trails, lists, basemaps, and popups?	100%
Can the user effectively access and interact with the information button and other relevant widgets?	100%
Can the user successfully select trails and delve into their specific details?	100%
Can the user change the basemap on the map without difficulties?	80%
Can the user clear the trail selection using the home button?	100%
Can the user find the specific route called Koppl Guggenthal to Nockstein 1?	100%
Is the visibility of the map and widgets clear for the majority of users?	84%

The first was about if the user is able to load the complete map with the trails, lists, basemaps and the popups, and the response was positive with 100% results.

Based on the data presented in the Table 8, it is evident that users can effectively access and interact with the information button and other relevant widgets. This functionality allows users to gather additional details, navigate trails, access lists, switch basemaps, and view popups seamlessly.

Additionally, the table demonstrates that users can successfully select trails and delve into their specific details. This capability enhances the overall user experience, empowering individuals to make informed decisions and tailor their exploration based on their preferences and requirements.

There was a positive response for the users have the ability to change the basemap on the map. However, it is important to note that during the testing phase, there were some instances where users experienced difficulties in loading the basemap. Out of the 25 participants, 80% of them were able to successfully change the basemap without any issues. On the other hand, 20% of the participants encountered challenges and experienced troubles in loading the basemap.

Please note that if the basemap fails to load, refreshing the page is recommended, as it may require a stable internet connection for proper loading. It is worth mentioning that a stable internet connection plays a vital role in ensuring the smooth functioning of the basemap feature.

Yes, users are able to clear the trail selection using the home button. The results for this particular question indicate a 100% positive outcome. All participants were able to successfully clear the trail selection by utilizing the home button functionality.

This demonstrates that the home button effectively resets the trail selection and allows users to start anew without any lingering selections. The home button serves as a convenient and reliable feature for users to easily clear their trail choices and begin exploring from a fresh starting point.

The next question was if the users can find the specific route, called Koppl Guggenthal to Nockstein 1, and the response to this request is 100% positive. The route between these two locations can be successfully determined and provided to users.

By utilizing mapping and navigation tools, users can receive detailed directions and guidance on how to reach Nockstein 1 starting from Koppl Guggenthal Volksschule. This ensures a seamless and efficient navigation experience, allowing individuals to reach their desired destination with ease.

Next three questions, 2.6, 2.7 and 2.8 were short answer type to check the response of functional accuracy

- The number of trails accessible after selecting the difficult filter is 6 trails.
- The estimated time it will take to reach Nockstein 2 from Koppl Guggenthal Volksschule is approximately 1.25 hours.
- The total length of the path from Koppl Guggenthal Volksschule to Nockstein 2 is approximately 1,741.9 meters.

There were some reported issues with the visibility of the map or the widgets. The positive response rate for this question was 84%. This indicates that 84% of the participants did not encounter any problems with the visibility of the map or the various widgets, such as buttons and overlays.

However, it is worth noting that 16% of the participants did face issues related to the visibility of the map or the widgets. These issues could include instances where the map did not load properly, certain widgets were not visible or functioning as expected, or other related visibility issues.

Identifying and addressing these concerns is crucial to ensure a seamless user experience. It is recommended to investigate the specific causes of these issues and implement any necessary improvements or fixes to enhance the overall visibility and functionality of the map and its associated widgets.

Additionally, It was found that there were some of the issues were there while selecting the trails, this issue was because of the overlapping of GeoJSON files limitations on overlapping. Which is easily fixable while converting the file formats.

5.3 Feedback and suggestions

In summary, users provided valuable feedback and suggestions to improve the app. One common concern was the overlapping of symbols on the map, suggesting the use of different colors or the ability to hide certain symbols. Users also found the symbology colors on the World Topo base and Topographic map hard to read, and the yellow background color for hikes in the sidebar menu was challenging to read, especially when selected. Some users reported that icons disappeared when zooming in on the map, and roads sometimes appeared broken. To enhance text visibility, users suggested adding a background or textbox behind the text that appears on top of routes. Using a terrain map instead of OSM was recommended for better representation of slopes. Users also faced difficulties with the 3D navigation feature and desired clearer instructions or a tutorial within the app. Improving the visibility of icons, refining the legend's color scheme, and optimizing the visualization of the popup window were additional suggestions provided. Overall, implementing these enhancements would make the app more user-friendly, improve readability, and provide a smoother and more enjoyable experience for users.

Here is a summary of the points mentioned:

- Symbols and Overlapping: Consider using different colors for symbols or providing the option to switch visibility to avoid overlap and improve readability.
- Symbology Colors on Topographic Map: Improve the readability of symbology colors, especially on the World Topo base and Topographic map.
- Sidebar Menu Components: Enhance the readability of the hikes' colors, particularly the yellow background, and make selected items easier to read.
- Zooming and Road Display: Address issues where icons disappear when zooming in and ensure roads are displayed without breaks.
- Text Visibility on Routes: Improve visibility by considering adding a background or textbox behind text that appears on top of routes.
- Terrain Map: Consider using a terrain map instead of OSM for better rendering of slopes.
- 3D Navigation: Investigate and resolve any issues with 3D navigation, allowing users to change perspective and view selected areas from a bird's eye view.

- Legend for Symbols: Include a legend for symbols on the map to provide clear explanations of their meanings.
- Instructions and Guidance: Provide instructions or a guided tutorial within the app to help users explore and understand its features more easily.
- Icon Visibility: Enhance the visibility of icons on the map to make them more noticeable and easier to spot.
- Color Scheme of the Legend: Consider improving the color scheme of the legend to make it less bright and ensure it harmonizes well with the basemap.
- Popup Window Visualization: Improve the visualization of the popup window, possibly by reducing the size of the comment box.

These insights can help in improving the user-friendliness, readability, and overall experience of the app.

5.4 Interviews

In the interviews conducted as part of the analysis, participants were asked a series of questions to gather their insights and feedback on the web application. The interviews aimed to understand the participants' experiences, preferences, and suggestions regarding the usability, functionality, and overall user experience of the application.

During the interviews, participants were encouraged to provide their honest opinions and share any challenges they encountered while using the application. They were also asked to express their thoughts on specific features, such as the search functionality, trail information, map visualization, and user interface design. Additionally, participants were invited to provide suggestions for improvements and any additional features they would like to see in the future.

The interviews provided valuable qualitative data, allowing for a deeper understanding of the users' perspectives and preferences. The feedback gathered during these interviews helped identify strengths and weaknesses of the web application, highlighting areas of success and areas that require further refinement.

Overall, the interviews played a crucial role in gaining insights directly from the users, enabling a more user-centered approach to the analysis and development of the web application. The feedback obtained from the interviews served as a foundation for making informed decisions and implementing enhancements to improve the user experience and meet the needs of the target audience.

5.5 Results of analysis

After analyzing both the user feedback and the graph results, the following comprehensive analysis and insights have been derived:

1. **Symbol Visibility and Overlapping:** Users expressed concerns about symbol visibility and overlapping on the map. This issue is further supported by the graph results, indicating that 84% of users reported issues with the visibility of map symbols and widgets. It is recommended to address this concern by implementing different colors for symbols or providing the option to toggle their visibility. This would improve symbol differentiation and enhance overall map readability.
2. **Symbology Colors on Topographic Map:** Users found the symbology colors on the World Topo base and Topographic map to be less readable. The graph results do not explicitly indicate this issue, but it aligns with the overall feedback provided. To enhance readability, adjusting the color scheme and contrast for symbology on these specific maps is recommended.
3. **Sidebar Menu Component Readability:** Users mentioned that the color scheme, particularly the yellow background for hikes in the sidebar menu, posed challenges in readability. Although the graph results do not directly reflect this feedback, it is crucial to consider user suggestions for improving the color choice or providing alternative options to enhance readability and usability.
4. **Zooming and Road Display:** Users reported instances where icons disappeared when zooming in on the map, and roads occasionally appeared broken. Although the graph results do not explicitly capture this issue, it is essential to address it as it impacts the overall functionality and user experience. Ensuring consistent icon visibility and maintaining road display integrity should be a priority.
5. **Text Visibility on Routes:** Users mentioned difficulties in reading text on routes, especially when displayed on top of map elements. Although this issue is not reflected in the graph results, it is a valid concern. Implementing background or textbox options for text on routes would improve visibility and readability, providing a better user experience.
6. **3D Navigation:** Users faced difficulties with the 3D navigation feature, as mentioned in the feedback. Although the graph results do not provide specific insights into this issue, it is crucial to address it. Improving the 3D navigation functionality, allowing users to change perspectives and obtain bird's eye views, would enhance the interactive nature of the app and provide a more immersive experience.
7. **Legend for Symbols:** Users suggested the inclusion of a legend for symbols, which is not explicitly reflected in the graph results. However, it is an essential suggestion to enhance user understanding and interpretation of the map symbols. Providing a clear and accessible legend would improve the overall usability and user experience.
8. **Instructions and User Guidance:** Users expressed the need for instructions or a guided tutorial within the app to assist them in navigating and understanding its features. Although not captured in the graph results, this suggestion is valuable. Incorporating instructions or guided prompts would help users effectively explore and utilize the app's capabilities.
9. **Icon Visibility:** Users commented on the lack of eye-catching icons on the map. Although this feedback is not specifically indicated in the graph results, it is worth considering for future improvements. Enhancing the visual prominence and

distinctiveness of icons would make them more noticeable and improve the overall usability of the app.

The analysis of user feedback and suggestions provides valuable insights for enhancing the app's functionality, visual appeal, and user experience. Addressing these areas of improvement would result in a more user-friendly and visually optimized application, ensuring that users can effectively navigate, interpret, and interact with the map and its features.

5.6 Further Discussion

The development and testing of the web application for hiking trail planning have yielded positive results and valuable insights. The usability test conducted with ten participants demonstrated the effectiveness of the application in terms of ease of use and user satisfaction. The participants were able to perform various tasks, such as searching for hiking trails and creating hiking plans, without encountering any major difficulties. This indicates that the web application's user interface and functionality were well-designed and intuitive. The positive feedback received from the participants further validates the success of the application. Users appreciated the simplicity and intuitiveness of the design, noting that it facilitated their navigation and interaction with the app. The inclusion of reviews and ratings for hiking trails was also highlighted as a valuable feature, providing users with additional information and insights when planning their hikes.

The implementation of various map layers, including country boundaries, country subdivisions, hiking trails, and places such as hotels and restaurants, significantly enhanced the visualization of the system's recommendations. The integration of the ArcGIS Maps SDK for JavaScript proved to be a suitable choice for this purpose. Additionally, the customization of basemaps using the Google Maps JavaScript API contributed to the overall user experience. The client-side user interface was carefully designed to be user-friendly and informative. UI elements such as the header, navigation bar, trail cards, filters, and trail details provided a seamless experience for users to search for and explore hiking trails. The use of libraries such as Material UI, Google-map-react, and Supercluster played a crucial role in implementing various features and functionalities, ensuring a smooth user experience.

The evaluation of the prototype through an online survey allowed for gathering feedback and opinions from users. By presenting participants with pictures of the prototype and asking them to assume different user roles, valuable insights were collected. The survey covered both objective and subjective aspects, enabling a comprehensive understanding of user preferences and expectations.

Overall, the development and evaluation of the web application demonstrated its effectiveness in providing a user-friendly platform for hiking trail planning. The positive feedback, ease of use, and intuitive design highlight the success of the implemented features and functionalities. The application has the potential for further expansion, such as incorporating weather forecasts and real-time trail conditions, to enhance the user experience and provide more comprehensive information.

In conclusion, the web application for hiking trail planning has proven to be successful in fulfilling its objectives. The combination of a well-designed user interface, integration of map layers, and valuable user feedback has contributed to its usability and effectiveness. The findings from the usability test and survey provide a solid foundation for future improvements and enhancements to meet the evolving needs of hikers and outdoor enthusiasts.

In addition to the discussed aspects, it is worth considering the applicability of Copernicus data for terrain modeling, weather, and vegetation. The integration of Copernicus data into the web application could bring valuable insights and enhance the overall user experience. For instance, utilizing Copernicus data for terrain modeling would allow hikers to better understand the topography of hiking trails, including elevation changes and steepness. This information can be crucial for assessing trail difficulty and planning accordingly.

Furthermore, incorporating Copernicus data for weather forecasts would provide users with real-time weather information specific to the hiking trail locations. Knowing the weather conditions in advance can help hikers make informed decisions regarding their trips, ensuring safety and comfort during their outdoor activities. By considering the potential integration of Copernicus data, the web application can broaden its scope and provide users with more comprehensive and insightful information for their hiking adventures. This expansion could contribute to a richer and more immersive experience, further establishing the application as a go-to resource for hiking trail planning and exploration.

Scope:

The project scope revolved around the development of a web application utilizing Node.js modules, which were chosen for their advanced capabilities and suitability for the task. The primary goal was to create an engaging and user-friendly application focused on hiking trails. The design process involved careful consideration of color schemes, typography, icons, and visual effects to enhance the overall user experience. Special attention was given to ensuring responsiveness and consistency across various devices and screen sizes, with a particular emphasis on desktop and landscape screens.

Furthermore, it is important to highlight that the application has the potential to be implemented on a larger scale. Its underlying technologies and design considerations make it suitable for expansion and adaptation to cater to a wider audience of hikers. With continued development and refinement, there is an opportunity for this application to become one of the most advanced and comprehensive tools available for hikers, offering a seamless and immersive experience for planning and navigating trails.

Limitations:

Despite the successful migration to Yarn and the integration of a Ruby environment, it's important to acknowledge the limitations of the project.

Firstly, while Node.js modules were chosen for their advanced features and capabilities, there may still be inherent limitations within the modules themselves. This could include

potential bugs, compatibility issues, or limited support for certain functionalities required by the application.

Secondly, the transition from NPM to Yarn as the package manager was made to overcome limitations and errors encountered during deployment, and it proved successful in resolving those issues. The integration of a Ruby environment was also incorporated to address specific requirements and enhance certain functionalities of the application.

Furthermore, while efforts were made to create a responsive design, it's important to note that achieving a seamless user experience across different devices and screen sizes can be challenging. Certain devices or screen resolutions may still present layout or usability issues that need to be addressed through further testing and refinement.

Lastly, the scope of the project focused primarily on the visual aspects and the integration of technologies, such as Node.js, Yarn, and Ruby. Other factors such as performance optimization, scalability, and security were not extensively discussed within the provided information and may require additional attention in a comprehensive evaluation of the application.

Despite the benefits of online visualization tools for hiking activities, there are some challenges and limitations that need to be addressed. One of the major challenges is the availability and accuracy of data. Online visualization tools rely on accurate and up-to-date data to provide hikers with the most relevant and useful information. However, in many cases, the data may be outdated or incomplete, which can lead to incorrect or misleading information.

Another challenge is the accessibility of online visualization tools. Not all hikers may have access to the internet or the necessary hardware to use these tools. This can create a digital divide, where some hikers may have an unfair advantage over others in terms of planning their hiking activities.

Overall, while the project successfully addressed the initial limitations faced with NPM and achieved the desired visual aesthetics and usability, it's important to continuously evaluate and address any potential limitations and challenges that may arise during the application's lifecycle.

Performance issues can become a significant limitation depending on the complexity and size of the application. The integration of multiple technologies, such as Node.js, Yarn, and Ruby, may introduce overhead and impact the overall performance. Thorough performance testing and optimization are necessary to ensure the application performs well under different scenarios and user loads.

Scalability can become a limitation as the user base and data load increase. The application should be designed and implemented in a way that allows for easy scalability, both in terms of handling increased user traffic and managing growing data volumes. This may require architectural considerations and potentially reengineering certain components.

6 CONCLUSION

The development and testing of the web application for hiking trail planning have resulted in a successful and user-friendly platform for users to find and plan their hiking adventures. The application's intuitive user interface, search functionality, and integration of map layers have provided users with a seamless experience in discovering and exploring hiking trails. Through the implementation of modern web technologies, such as Node.js for both frontend and backend, the application was able to deliver a responsive and efficient platform. The use of libraries like Material UI and Google-map-react contributed to the overall user experience by providing well-designed UI elements and interactive map features.

The usability test conducted with a group of participants confirmed the effectiveness of the application. All participants were able to easily complete tasks such as searching for hiking trails and creating hiking plans. Their positive feedback highlighted the simplicity, intuitiveness, and usefulness of features such as the reviews and ratings system.

The integration of various map layers, including country boundaries, hiking trails, and places of interest, allowed users to visualize recommendations and plan their hikes effectively. The use of the ArcGIS Maps SDK for JavaScript and customization of basemaps using the Google Maps JavaScript API provided a visually appealing and informative map interface. The evaluation of the prototype through an online survey further validated the application's success. The feedback received from participants helped identify areas of improvement and provided valuable insights for future enhancements.

The development of the web application involved leveraging Node.js modules and advanced technologies to create a visually appealing and user-friendly experience for hiking trail enthusiasts. The migration from NPM to Yarn as the package manager proved successful in overcoming limitations and errors encountered during deployment, providing a more efficient and reliable environment. The integration of a Ruby environment further enhanced specific functionalities of the application. Efforts were made to ensure a responsive design, allowing for a consistent user experience across various devices and screen sizes, with a focus on desktop and landscape screens. The selection of colors, typography, icons, and visual effects contributed to the overall aesthetics and usability of the application.

However, it is essential to acknowledge the potential limitations within the chosen technologies and the complexities introduced by the transition process. Ongoing testing, refinement, and consideration of factors like performance optimization and security will be crucial for the continued success and improvement of the application.

In conclusion, the web application for hiking trail planning has proven to be a valuable tool for users seeking to explore and plan their hiking experiences. The user-friendly interface, comprehensive map layers, and positive user feedback highlight the application's effectiveness in meeting the needs of hiking enthusiasts.

Further development and enhancements, such as incorporating weather forecasts and real-time trail conditions, can elevate the application to even greater heights. Overall, the web application has successfully fulfilled its purpose of providing a platform for users to find and plan hiking trails, facilitating their journey towards memorable outdoor experiences. Additionally, the project demonstrated the adaptability and innovation required to overcome challenges and deliver a compelling web application. With careful attention to user experience and the utilization of advanced technologies, the application has the potential to provide an enjoyable and seamless experience for hiking enthusiasts.

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ATTACHMENTS

LIST OF ATTACHMENTS

Free attachments

- Attachment 1 Poster
- Attachment 2 Webpage
- Attachment 3 Source code ([https://github.com/exploringravi/lets hike.](https://github.com/exploringravi/lets hike))
- Attachment 4 User evaluation form (attached below)

Online Visualization of hiking activities (Web-based application for hiking activity)

Dear Participant,

I am Ravi, a CDE M.Sc. student at the University of Salzburg, Austria, and Palacký University Olomouc, Czechia. Thank you for taking the time to participate in this survey on the topic of Online Visualization of hiking activities (Web-based application for hiking activity). This survey is being conducted as part of my thesis, which aims to explore the development of a web-based application for hiking activities.

The purpose of this survey is to gain insight into your experience and preferences when it comes to hiking activities and online tools. Your input will help to inform the design and development of an online visualization tool for hiking activities.

Please answer the following questions to the best of your ability. The survey should take approximately 10-15 minutes to complete. Your responses will be kept confidential and will only be used for research purposes.

In case if you have any questions or suggestions, can reach me out at ravi@cityai.space

Ravi PANDEY

CDE M.Sc. student

University of Salzburg, Austria and Palacký University Olomouc, Czechia

* Indicates required question

1. Email *

Section 1: General Questions

2. 1.1 Full Name *

3. 1.2 What is your gender? *

Mark only one oval.

1. Female

2. Male

3. Other

4. 1.3 How old are you? *

Mark only one oval.

1. 18-29

2. 30-39

3. 40-49

4. 50-59

5. 60+

5. 1.4 What kind of trips have you conducted? *

Check all that apply.

1. Hiking

2. Skiing

3. Climbing

4. Mountain biking

5. Surfing

6. Other trips related to outdoor activities

7. None of them

6. 1.5 What applications do you generally use for planning your above-mentioned trips and how often?

Check all that apply.

	Not at all	Seldom	Sometimes	Often	Very often
Google Maps	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TripAdvisor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AllTrails	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Komoot	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Outdooractive	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
FATMAP	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

7. In case you use any other applications, please name them here.

8. 1.6 Please rate the following statement:

Mark only one oval per row.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I think I am a confident user of web mapping applications (e.g. Google Maps, AllTrails, Komoot, etc.).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

9. 1.7 What applications do you generally use for planning your trips and how often? *

* For respondents without travel experience (When answering “None of them” in Q1.4)

Check all that apply.

	Not at all	Seldom Sometimes	Sometimes	Often	Very often
Google Maps	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TripAdvisor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Booking.com	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Foursquare	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Yelp	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>MAPS.ME</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10. In case you use any other applications, please name them here.

11. 1.8 Please rate the following statement: (reference to the question 1.7)

Mark only one oval per row.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	N/A
I think I am a confident user of web mapping applications (e.g. Google Maps, maps.me, etc.).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 2: Visual expressions

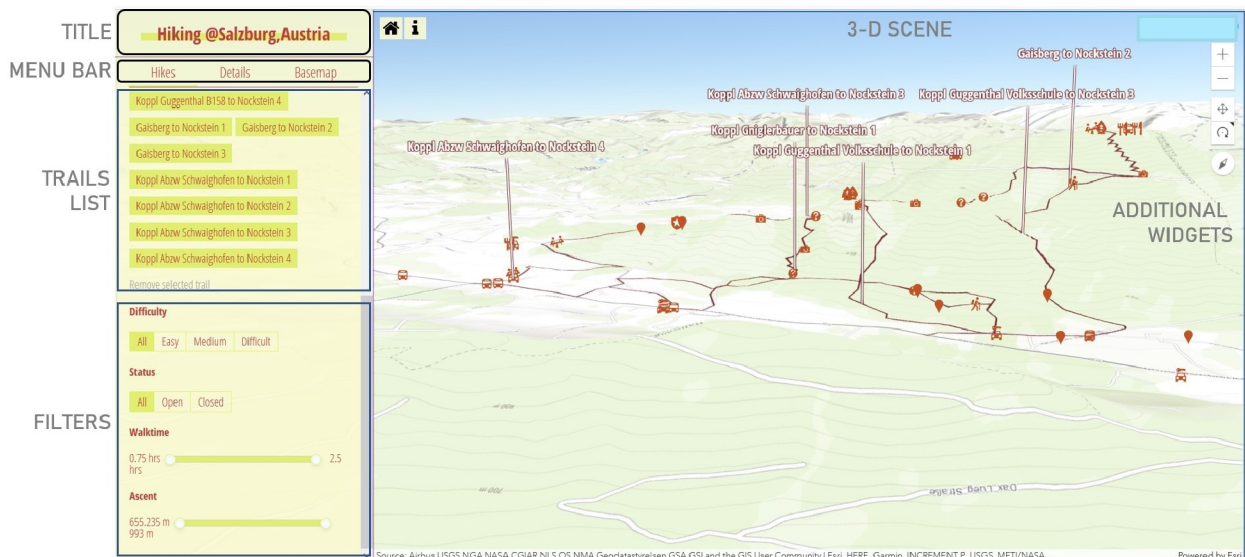
Important note: The interface and data used in the prototype are not final and for testing purposes only.

Please pay attention to the design and visualizations related to the map.

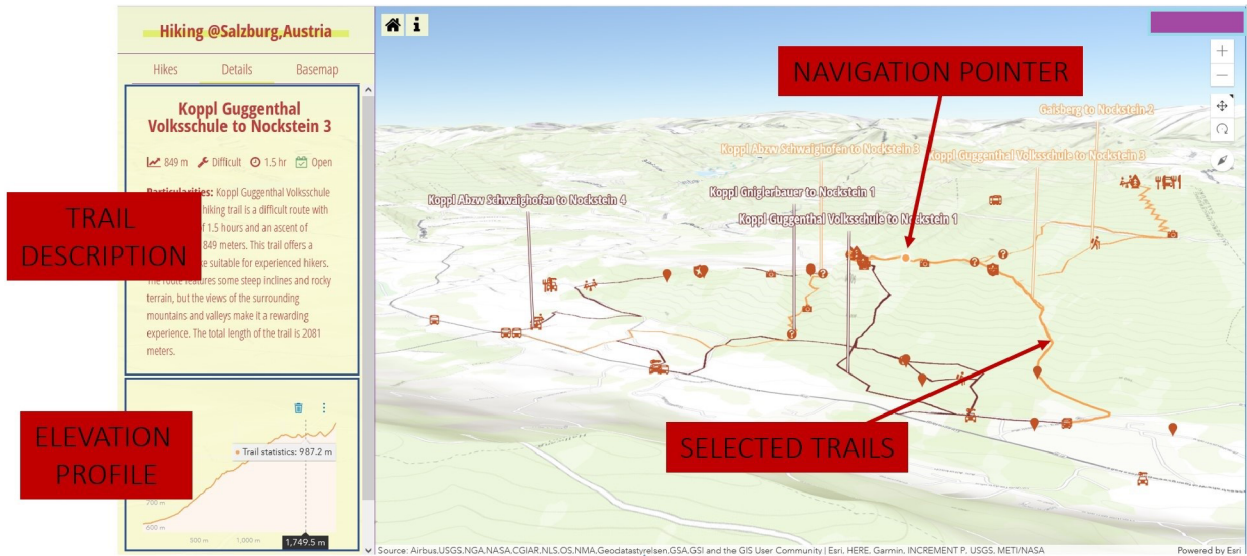
Please click on the following link to open the draft web app: <https://letshike.netlify.app/> and go to the exploration page. The study area is the Mountain range in Koppl, Salzburg, Austria, situated in the Alps mountain range. The app currently contains basic amenities.

On the exploration page, you will see a map with countries colored in white and different shades of grey. You can select Europe as your continent, October as your month, and Hiking as your activity. Based on your selections, the map will display recommended hiking trails, landmarks, and restaurants and other amenities in the selected area.

Please explore the web app and answer the following questions:



This web-app is currently more friendly for the desktop, as it is in developing stage.



12. 2.1 Are you able to load the map completely? *

Mark only one oval.

Yes

No

Maybe

13. 2.2 Are you able to see and explore the information button and other widgets?

Mark only one oval.

Yes

No

Maybe

14. 2.3 Can you select the trails and explore their details? *

Mark only one oval.

- Yes
 No
 Maybe

15. 2.4 Can you change the basemap on the map? *

(in case if its not loading, please refresh the page: it require stable internet to load)

Mark only one oval.

- Yes
 No
 Maybe

16. 2.4 Are you able to clear the trail selection using the home button? *

Mark only one oval.

- Yes
 No
 Maybe

17. 2.5 Can you find a route Koppl Guggenthal Volksschule to Nockstein 1?

Mark only one oval.

- Yes
 No
 Maybe

18. 2.6 How many trials are accessible after selecting the difficult filter?

19. 2.7 How much time it will take to reach by using Koppl Guggenthal Volksschule to Nockstein 2 path?

20. 2.8 Total Length of Koppl Guggenthal Volksschule to Nockstein 2 path?

21. 2.9 Were there any issues with the visibility of the map or the widgets? *

Mark only one oval.

Yes

No

22. If yes, what is that?

23. 2.10 Were there any difficulties in selecting and exploring the trails? *

Mark only one oval.

Yes

No

24. If yes, what is that?

25.

2.11 Were you able to find the information you were looking for regarding restaurants and other amenities?

Mark only one oval.

Yes

No

Maybe

26. 2.12 Was the visibility of the basemap satisfactory in terms of readability and color contrast?

Mark only one oval.

Yes

No

Maybe

27.

2.11 Would you suggest any improvements regarding the visibility of the map, widgets, or other components of the app?

Mark only one oval.

Yes, I have suggestions for improving the visibility of the app.

No, I think the visibility of the app is satisfactory.

28. Suggestions

In Addition

29. 3.1 If you have some additional comment, suggestion or query

Dear participants,

I would like to extend my heartfelt thanks for taking the time to complete this questionnaire on the Online Visualization of Hiking Activities. Your input and feedback will help me to improve the design and functionality of the web-based application for hiking activity. Your participation in this study is greatly appreciated, and your contributions will help to make this app more user-friendly and effective for hikers like yourself.

Thank you once again for your valuable time and insights.

Sincerely,

Ravi

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