SAil ARrrr

Use of Augmented Reality for Visualizing Ambient Conditions while Sailing

Semester Thesis

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Image source: https://devrant.com/rants/1175993/is-this-the-future-we-are-heading-to

Abstract

Introduction

Navigating a sailing boat successfully requires a deep understanding of the surrounding environment. Common sailing instruments, which display information numerically or in 2D graphs, often require considerable experience and spatial imagination for interpretation. This thesis explores the potential of Augmented Reality in enhancing the visualization of ambient conditions, offering a more intuitive and informative approach to sailing navigation.

Goal

The primary goal of this thesis is to evaluate the practicality and effectiveness of integrating Augmented Reality into sailing. Employing a human-centered approach, it aims to develop and validate scenarios where Augmented Reality can enhance the sailing experience, focusing on both usability and technological feasibility.

Method

This research commenced with an extensive literature review to assess the current state of Augmented Reality applications in sailing and related domains. This was complemented by conducting five targeted interviews with a diverse group of sailors, ranging from novices to experts, to gather insights into their specific needs and preferences when sailing. This dual approach allowed for a comprehensive understanding of both the theoretical and practical aspects of Augmented Reality in sailing.

Results

The analysis yielded a series of detailed personas and Augmented Reality application scenarios. These personas represent a spectrum of user needs and preferences in the sailing community. For the most promising scenario, a hardware component architecture was designed, laying the groundwork for future practical implementation. These results collectively provide a nuanced understanding of how Augmented Reality can be tailored to enhance the sailing experience.

Recommendations

The thesis concludes that Augmented Reality holds significant promise for enriching the sailing experience by offering enhanced perception and understanding of ambient conditions. However, the current state of AR technology, particularly in terms of maritime durability and waterproofing, poses a challenge. Consequently, it is recommended to monitor ongoing technological advancements in Augmented Reality. In the meantime, exploring interim solutions or adaptations that can bridge the gap until Augmented Reality technology matures for maritime conditions would be beneficial for the sailing community.

Acknowledgments

My sincere thanks go to my advisor Frieder Loch for his guidance, writing assistance, and mental cheer-ups throughout this semester.

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Lastly, I wish to express my gratitude to Richard Socher for bringing neural networks into the field of natural language processing.

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1 Introduction

Preamble This chapter serves as an overview of the entire thesis. It begins with a brief discussion of the complexities of sailing, proceeds to describe the primary aim of this thesis, and provides an overview of the methodology that was employed.

1.1 The Challenges of Sailing

Introduction Sailing is a skillful blend of art and science, particularly evident in the understanding and utilization of wind and the selection of sailable courses. This section briefly explores these core challenges, setting the stage for the potential enhancements that Augmented Reality can offer in this domain.

Wind One of the most significant challenges in sailing is the mastery of wind. Sailors must read and interpret wind patterns, which are often unpredictable and change rapidly. Understanding wind direction, strength, and shifts is crucial, as these factors directly influence the boat's speed and maneuverability.

Course Navigating a sailboat also involves the strategic selection of sailable courses. This requires not just an understanding of the wind but also the ability to plot a course that maximizes efficiency and safety. Sailors must constantly make decisions about the best angles to sail relative to the wind, considering factors like current, tide, and potential hazards.

Figure 1 illustrates the "no-sail zones" for a sailboat, depicted in gray. These zones represent the angles at which a sailboat cannot sail, typically around 40° to 45° on either side of the wind direction. Additionally, the diagram highlights the downwind area, where sailing is also challenging. The exact angles of these 'no-sail zones' can vary depending on the type and design of the boat, reflecting differences in sailing capabilities and characteristics.

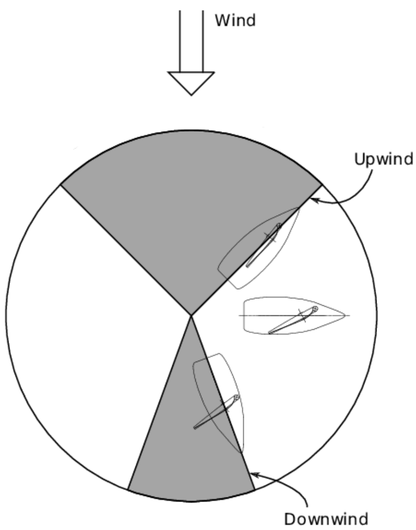

Figure 1: Possible courses of a sailing boat with respect to the wind [1]

Points of Sail Given the wind direction and the chosen course, the positions of the sails are determined. The adjustment of the sails to optimize their shape and angle is key to harnessing the wind's power effectively. It is a dynamic process, requiring continuous attention and fine-tuning. Effective sail trim balances the boat's speed and stability, and is essential for navigating efficiently and safely in varying wind conditions.

Figure 2 illustrates the various points of sail in relation to the wind direction. It also highlights the "no-sail zone", where the sails are unable to generate sufficient force for movement, leading to flapping and loss of control.

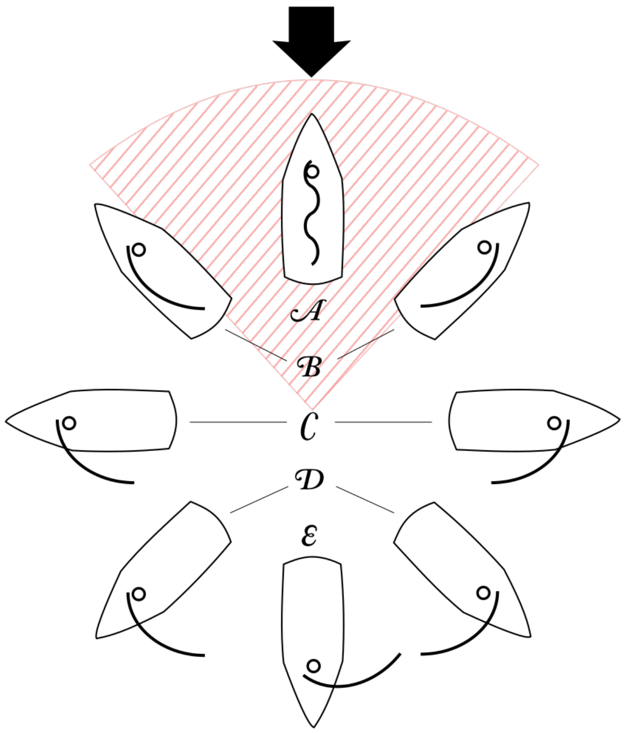

Figure 2: Points of sail with shaded "no-sail zone"[1]
A: Into the wind B: Close-hauled C: Beam reach D: Broad reach E: Downwind

[1] https://en.wikipedia.org/wiki/Point_of_sail

Common Instruments

Due to the reliance on wind in sailing, various tools are utilized to assist in determining the wind direction. Nowadays, this task is often accomplished using electronic instruments.

Figure 3 depicts an electronic wind indicator. The blue outline represents the boat and aligns with the boat's actual axis. The red pointer indicates the direction from which the wind is coming. In this example, it is approximately 120° from the starboard side. This corresponds in *Figure 2* to a sail position of *Broad reach*, represented by the left boat marked with a *D*. Additionally, the wind speed is also displayed, indicating 5 knots.

Figure 3: Common sailing instrument. Displaying wind angel (red indicator) relative to the boat (blue outline) and wind speed in knots[2]

Cognitive Challenge

Translating the abstract information provided by these instruments into practical application requires good spatial imagination and experience. The 2D representation of wind direction and speed on common instruments can be challenging to interpret in a real-world, three-dimensional sailing context. Sailors must mentally visualize how the wind interacts with their sails and course, a skill that typically develops with practice and time. This could be simplified by Augmented Reality.

[2]https://www.outbackmarine.com.au/garmin-gmi-20-marine-instrument

1.2 The Aim of this Thesis

Introduction

The primary aim of this thesis is to explore and evaluate how Augmented Reality technology can be integrated into the realm of sailing to address its challenges. This exploration involves a detailed assessment of the practicality and effectiveness of AR in enhancing sailing experiences.

Usability

Central to this thesis is a human-centered approach, which prioritizes the user experience in sailing contexts. This involves understanding the needs and preferences of sailors of varying levels of expertise and designing AR interfaces that are intuitive, informative, and easy to use. The goal is to reduce the cognitive load associated with common sailing instruments, making navigation and sail management more accessible, especially for those with less experience.

Technological Feasibility

Alongside usability, this thesis delves into the technological aspects of implementing AR in sailing. This includes examining the current state of AR technology, its potential for integration with existing sailing equipment, and the development of new solutions. The feasibility study considers factors such as the durability of AR devices in marine environments, their ability to operate effectively under various weather conditions, and the integration of real-time environmental data.

1.3 Methodology

Introduction

The methodology of this thesis was designed to be comprehensive and multifaceted, encompassing both theoretical and practical perspectives on the integration of Augmented Reality in sailing. It is divided into four parts: Research, User Study, Scenarios, and Architecture.

Research

The first part involved an extensive literature review, aimed at assessing the current state of Augmented Reality applications in sailing and related domains. This entailed a thorough analysis of systematic reviews and case studies to understand the advancements, challenges, and gaps in the field. This review lays the foundation for the *Research* chapter, which delves into these findings in greater detail.

User Study

The second part consisted of conducting targeted interviews with a diverse group of five sailors. This user study was crucial in gathering firsthand insights into the specific needs and preferences of sailors with varying levels of experience. The outcomes of these interviews are the focus of the *User Study* chapter, which presents a detailed analysis of the interview data and the development of personas representing the sailing community.

Scenarios

Building on the insights from both the research and the user study, the third part involved developing potential Augmented Reality scenarios for sailing. This part is conceptualizing how Augmented Reality could be practically applied to meet the needs and challenges of the sailing community. In the *Scenarios* chapter, a detailed exploration of these applications is presented, including the primary scenario *Sailing Course Assistant*.

Architecture

The final part of the thesis addresses the technical implementation of Augmented Reality in sailing, specifically through the proposed architecture for the *Sailing Course Assistant* scenario. The *Architecture* chapter outlines a system that balances both hardware and software needs. It discusses how this architecture integrates with existing sailing equipment and addresses technological challenges.

2 Research

Preamble

Building on the literature review, this chapter delves deeper into the findings from academic and industry sources, discussing the state-of-the-art in Augmented Reality technology and its current applications in sailing and similar environments.

2.1 Augmented Reality

Introduction

Augmented Reality (AR) is a technology that combines the real world with computer-generated information. It enhances a user's perception by overlaying digital content onto the real-world view. The content can involve text or 3D graphics.
Milgram et al. [2] have introduced the concept of a mixed reality. As seen in *Figure 4* they defined a reality-virtuality continuum representing a spectrum of experiences ranging from the entirely real world to the entirely virtual world. On this spectrum, Augmented Reality is more on the side of the real environment.

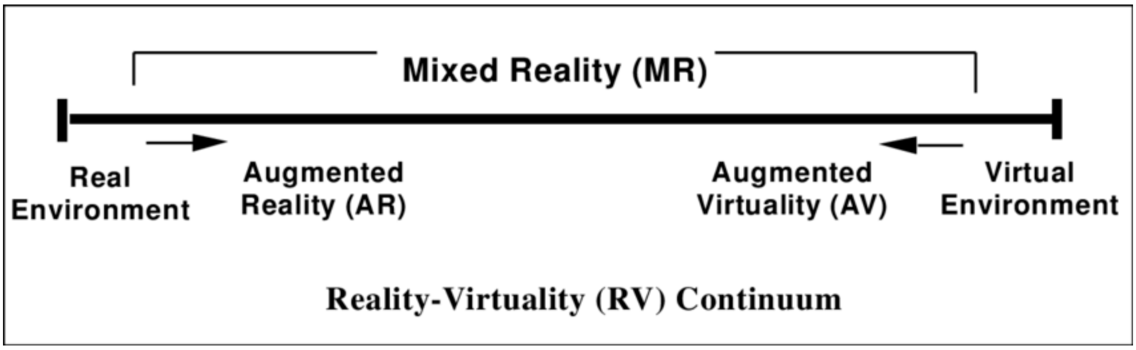

Figure 4: Reality-Virtuality Continuum by Milgram et al. [2]

Applications

Augmented Reality is utilized across various domains.

- **Guidance**: In manual assembly, AR aids operators by providing instructions. *Figure 5 (a)* demonstrates how the physical reality is enhanced with information on task completion, without occupying the operator's hands. Enabling the operator to focus on the manual task and optimizing cognitive resources.
- **Expand reality**: AR is employed to visualize non existent objects or concepts. *Figure 5 (b)* illustrates how applications can virtually showcase furniture in a user's living space. This empowers individuals to envision how diverse pieces of furniture might appear in their rooms and interact seamlessly with their current environment. Users can experiment with different colors, styles, and arrangements, enhancing their ability to make informed decisions.
- **Visualize the unseen**: AR unveils objects that would remain invisible under normal circumstances. Comparable to X-ray technology, this allows for a peek into objects. *Figure 5 (c)* demonstrates how underground infrastructure is made visible. Such as water pipes, gas lines, or electrical conduits.

- **Visualize data**: AR transforms abstract numbers into tangible reality. In *Figure 5 (d)* computer network traffic is visualized, providing a dynamic and interactive representation. This enables users to gain a real-time understanding of complex data patterns, enhancing their ability to monitor and respond to changes efficiently.

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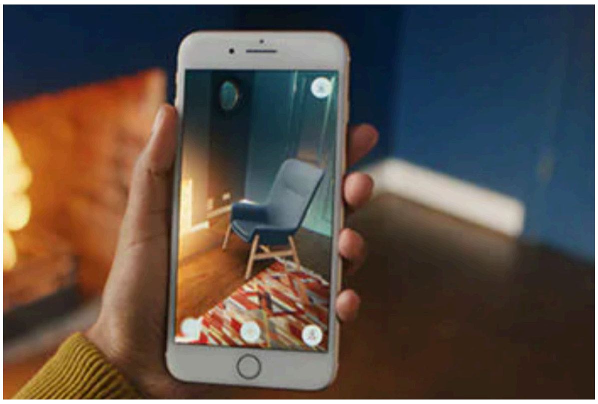

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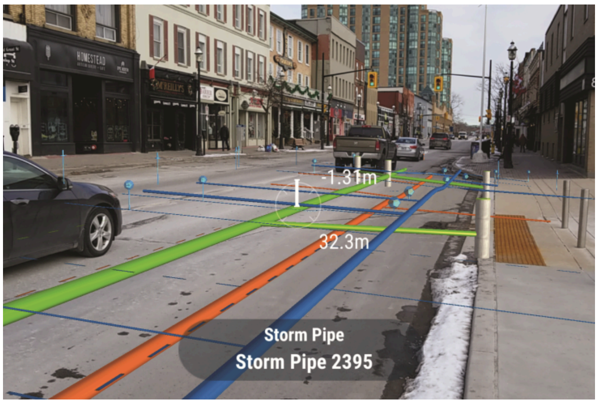

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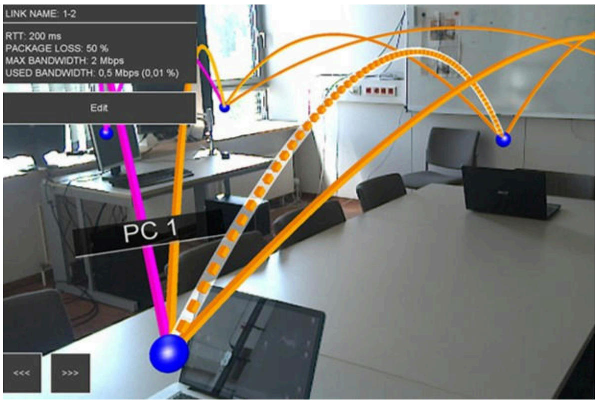


(*d*)

Figure 5: Augmented Reality applications (a) AR guidance during assembly[3] (b) AR reality expansion with furniture[4] (c) AR underground infrastructure visualization[5] (d) AR network traffic visualization[6]

[3] https://www.press.bmwgroup.com/global/photo/detail/P90343106/Training-new-staff-is-supported-by-augmented-reality-glasses-and-virtual-assistance-at-the-assembly
[4] https://www.ikea.com/de/de/this-is-ikea/corporate-blog/ikea-place-app-augmented-reality-puba55c67c0
[5] https://www.xyht.com/constructionbim/visualizing-hidden-infrastructure-in-3d/
[6] https://imld.de/en/research/research-projects/ar-graph-vis/

Hardware

Augmented Reality is showcased on various devices.

- **Optical see-through AR displays** display the digital content directly on a transparent glass into the user's field of vision. The physical reality is still visible through the glass.
  - *Head-mounted displays (HMD)* are worn on the head. Infomally often referred to as smartglasses. An example of an HMD is the Microsoft HoloLens, shown in *Figure 6 (a)*.
  - *Head-up displays (HUD)* are mounted in front of the user. For example, integrated into a car windshield, as illustrated in *Figure 6 (b)*.
- **Video see-through AR displays** utilize a camera to capture the real world and insert digital content into the video. The camera and display can either be integrated into the same device, as seen in *Figure 5 (b)* with the smartphone app. Or camera and display are separate components.

(*a*) (*b*)

Figure 6: Augmented Reality hardware (a) HMD Microsoft HoloLens[7] (b) HUD in a car windshield[8]

[7] https://www.microsoft.com/en-us/industry/blog/manufacturing-and-mobility/2019/06/17/workforce-transformation-in-the-intelligent-manufacturing-era/

[8] https://www.gizmochina.com/2021/11/29/volvo-new-tech-car-windshields-ar-display/

2.2 Augmented Reality in Sailing

Introduction

Understanding the relationship between wind, boat, and course is fundamental for sailing. The wind acts as the primary force shaping the direction in which the boat can navigate. The dynamic interplay of wind and chosen course dictates the optimal sail position.

The wind is not a constant force. It changes in direction and intensity. Consequently, continual adjustments to the course and sails are required.

However, the wind itself can not be seen. Its direction can only be recognized through observation. Either through tactile sensations, such as the feel on the skin, or by observing responsive elements like flags or waves that react to the wind's influence.

Furthermore, there is the challenge of navigation. Maps are used for orientation on the water. They must be read and interpreted accurately to safely maneuver to the destination, avoiding collisions with obstacles, shallows, and other vessels.

Application of AR

The integration of Augmented Reality into sailing holds the potential to address a spectrum of challenges. The capability for data visualization can be utilized to better understand the surrounding environment. For example, the wind or relevant information for navigation. Augmented Reality demonstrates expertise in making the invisible visible, such as underwater obstacles or changes in depth. It can be used to visually guide and provide precise instructions on sail positioning and maneuvers.

There is already research concerning AR and sailing that will be reviewed in the following.

2.2.1 Systematic Review

Component Types

Gernez et al. conducted a review on AR application on ship bridge operations [3]. They discussed different information components to render AR information in the environment.

- **App display:** This component allows the display of full applications in the AR view.
- **Widget display:** This allows the display of smaller stackable information containers.
- **Annotation:** These are small information containers connected to Points Of Interest (POIs) in the world. Example: information about surrounding vessels and objects.
- **Ocean overlay:** This allows the display of information directly on the ocean. It typically shows routes and no-go zones.
- **AR map:** This is a flat map interface placed above the horizon, able to display any map-related information.

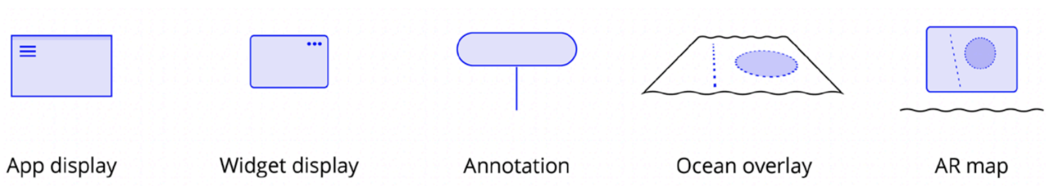


Figure 7: Types of AR information components by Gernez et al. [3]

Widget, annotation and ocean overlay are the most used component types in the reviewed applications.

Technology Development

Gernez et al. explore the current status of Augmented Reality technology [3], noting that it is still in the early stages of development. They suggest that AR could play a significant role in future maritime workspaces. Drawing a parallel with the evolution of mobile phones, they foresee an expansion in AR functionalities as technology progresses. This analogy is visually represented in Figure 8, where the current state of AR technology, exemplified by the Microsoft HoloLens, is compared to early mobile phones. They predict that, much like with mobile phones, the advancement of AR hardware will lead to a broader spectrum of applications and uses.

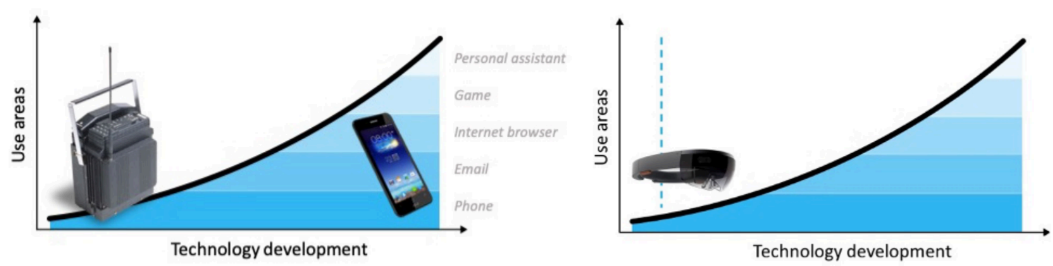


Figure 8: Technology development comparasion of mobile phones and AR displays by Gernez et al. [3]

2.2.2 Applications

AR Effectivity Evaluation

Laera et al. evaluated an AR-based interface for sailing navigation and compared it to regular 2D sailing instruments [4]. They conducted a user study (n=45) in a virtual reality simulated environment. They measured the reaction time and subjective metrics using user experience questionnaires.
Their results show that the AR-based interface outperformed common instruments in terms of reaction time, cognitive load, system usability, and user experience.

AR Sailing Interfaces

Laera et al. designed three AR interface proposals for sailing application [5] .

- **Screen-Stabilized Interface** displays essential boat information in the upper part of the user's field of view. The data is displayed in numerical form or as graphs, like in conventional 2D sailing instruments. The interface is designed for coastal navigation during recreational sailing and is suitable for users with sailing experience.

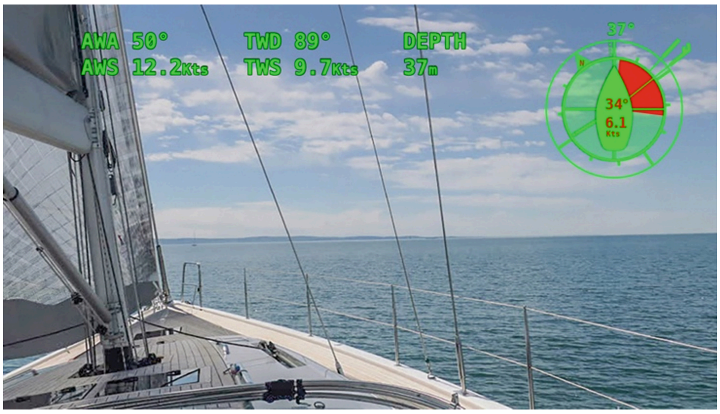


Figure 9: Screen-stabilized AR 2D interface proposal by Laera et al. [5]

- **Body-Stabilized Interface** displays a 3D boat avatar tied to the user's hand that is aligned with the real boat's orientation. It is designed for sailing beginners and shows abstract vectors for meteorological phenomena. They help the user better understand the sailing process by visualizing the forces acting on the boat.

Figure 10: Body-stabilized AR 3D interface proposal by Larea et al. [5]

- **Boat-Stabilized Interface** displays ambient information placed in the surrounding environment using graphics centered around the boats mast. It is suitable for both recreational use and for regatta applications. The interface features a high level of information detail and is useful for navigation.

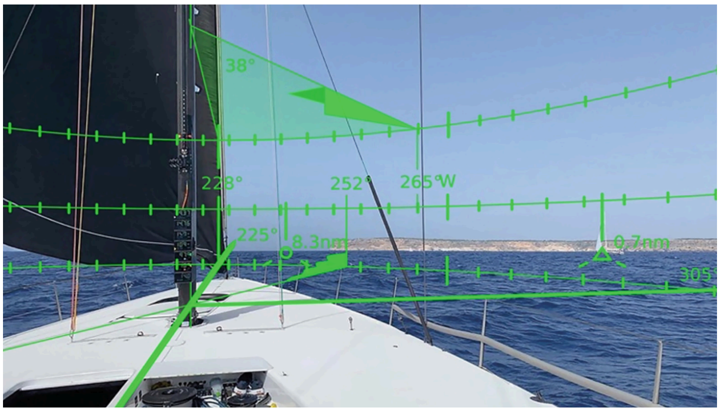


Figure 11: Boat-stabilized AR 3D interface proposal by Larea et al. [5]

Hardware Requirements

Laera et al. specified requirements a head-mounted AR display should fulfill for use while sailing [6]. They defined the following points:

- Withstand elements like water, UV rays, temperature drops, wind, humidity, and salt spray.
- Impact resistant and securely fixed to the user's body because of the frequent collision with rig elements (e.g. ropes, boom, etc.) and crew, especially during regatta.
- Compatible with the floatation devices, low weight, and designed to avoid risks head injury during the impact with the water at speed in case of man overboard.
- Ergonomic and easy to wear.

There is currently no head-mounted display available that meets the specific requirements, especially with regard to the required water resistance.

2.3 Discussion

Use of AR in Sailing

The utilization of Augmented Reality in a maritime context has garnered limited scientific attention. However, Dr. Francesco Laera and his team at the Polytechnic University of Bari are playing a pivotal role in this niche area, primarily through their foundational research. The three design prototypes for Augmented Reality interfaces are building a foundation for the scenarios developed in this thesis.

All the studies conducted to date underscore the effectiveness of augmented reality in sailing applications. User studies indicate that AR interfaces can significantly enhance reaction times and overall user experience during sailing. For beginners, Augmented Reality offers an intuitive means to grasp the fundamentals of sailing, while for seasoned sailors, it provides valuable assistance in navigation and boat handling.

Component Types

Many component types used in Augmented Reality applications on ship bridges are not well-suited for sailing applications, primarily because they obstruct the user's view. The only component type that can be effectively adapted for sailing is the annotation system.

One innovative concept not yet fully explored in these applications is the display of information in the sky. As observed in other studies, this approach seamlessly integrates information with the natural surroundings, improving both the usability and safety of navigational aids.

AR Technology

The development of head-mounted Augmented Reality displays is currently in its early stages, and existing models do not yet meet the demands of the nautical environment encountered in sailing. Challenges such as exposure to water, sunlight, and the dynamic motion of a boat present significant hurdles. However, as this technology continues to advance, it is anticipated that these challenges will be addressed and overcome in the future. This progress will likely lead to Augmented Reality displays that are fully equipped to handle the unique conditions of the maritime setting.

3 User Study

Preamble

This chapter details the methodology, execution, and findings of the interviews. It presents the creation of personas based on the interview data, reflecting the diverse needs and preferences of the sailing community. These personas are instrumental in designing scenarios that are closely aligned with real-world requirements.

3.1 Interviews

Introduction

In the pursuit of developing a deeper understanding of how Augmented Reality can be most effectively integrated into the sailing experience, this chapter delves into the heart of the sailing community itself. The decision to conduct interviews was driven by the need to gain direct insights into the diverse needs, preferences, and challenges faced by sailors. The goal of the interviews is not merely to collect data but to empathize with and understand the community for whom these applications are being developed.

Participant

In conducting the interviews for this thesis, it was essential to gather perspectives from a variety of sailors to ensure a comprehensive understanding of different sailing experiences. Accordingly, five individuals with diverse backgrounds and expertise in sailing were interviewed.

Four participants are affiliated with the Yacht Club Rapperswil (YCR), which organizes sailing courses at the OST each semester. Within this group, two have evolved into trainer roles, leveraging their experience to educate the next generation of sailors. The other two are fellow students who were met during sailing courses. The fifth participant comes from personal acquaintances.

Table 1 provides a detailed overview of the sailing backgrounds and levels of the five interview participants. Two of them are primarily involved in the cruising world, navigating yachts across oceans, while the other three have a focus on regatta sailing, maneuvering smaller boats in competitive settings. The table also displays the varied mix of levels among the participants, ranging from intermediates to professionals.

#	Sailing Background	Sailing Level	Connection
1	Regatta	Professional	YCR
2	Regatta	Advanced	YCR
3	Regatta	Intermediate	YCR
4	Cruising / Regatta	Advanced / Beginner	YCR
5	Cruising	Advanced	Acquaintance

Table 1: Sailing characteristics of the 5 interview participants.

Methodology

The interview process was meticulously designed to extract valuable insights while minimally influencing the participants responses. This was achieved by carefully structuring the questions and beginning with a brief onboarding session to introduce the thesis and its objectives.

To create a relaxed and open dialogue, the interview started with a light, non-critical question. Although not directly related to the thesis, this approach was effective in establishing a comfortable atmosphere for both the interviewer and the participants. The next set of five questions aimed to delve into the participants sailing backgrounds.
The subsequent questions were focused on uncovering the specific needs and challenges faced in sailing. This helped in gaining deeper insights into the practical aspects of the sport.
During the interviews with the trainers, emphasis was also placed on the experiences they observe in their students, particularly focusing on those aspects with which the students find challenging and struggle.
The interview concluded with an open question to encourage participants to think creatively and expansively.

Questions

Ice breaker

1. What is your first sailing experience?

Sailing background of participant

2. On what types of boats have you sailed or do you primarily sail?
3. What interests you in sailing?
4. What type of sailor are you? (Leisurely, racing, cruising, professional, etc.)
5. How would you rate your sailing level?
6. Where do you usually sail?

Sailing challenges and needs

7. What was difficult for you as a beginner in sailing?
8. What do you find challenging in sailing today?
9. How do you prepare for a sailing trip? Any rituals or checks?
10. What kind of information do you need while sailing?
11. What tools or technology do you use while sailing?
12. What do you have to pay attention to while sailing?
13. What are the dangers of sailing?
14. What would you like to try or learn in sailing in the future?

Final question

15. What tools or gadgets would you wish for in an ideal world?

3.2 Results

Introduction

This section will present the key findings from the interviews, with an emphasis on evaluating insights for potential improvements through Augmented Reality.

Cruising and Regatta

The most significant differences in responses are influenced by the participants' sailing backgrounds, specifically whether they are regatta sailors or cruisers.

Participants who engage in cruising place less emphasis on the technical precision of sailing. Instead, their focus is broader, encompassing the overall voyage. This includes crew handling or the efficient management of essential resources like food, water, and fuel. Furthermore, weather conditions have a major influence on their planning for routes and daily activities.

On the other hand, regatta sailors demonstrate a different set of priorities. Their focus is centered on optimizing performance, with a significant emphasis on perfecting boat handling and finding the optimal course. This involves meticulous attention to detail in every aspect of sailing, from the precise adjustment of sails to capitalizing on wind patterns and water currents for competitive advantage.

Sailing Level

In examining the responses of regatta sailors, a notable distinction emerged based on their level of experience. Experienced sailors exhibit a proficiency in boat handling that appears almost instinctual. For them, operating the boat does not require conscious thought or effort. This automaticity in handling their vessel frees up cognitive resources, allowing them to focus more on strategic aspects of sailing, such as monitoring wind conditions or observing competitors' movements.

In contrast, beginner sailors display a different set of priorities and challenges. These sailors often need to consciously think through each action in boat handling, which requires a significant amount of cognitive effort and concentration. This limits their capacity to focus on the surroundings.

Wind and Course

Every participant, regardless of their sailing background, underscored the importance of wind and course. These aspects were especially central for the regatta sailors, for whom they form the core of their focus during sailing.

Regatta sailors are constantly observing the wind, its direction, strength, and changes. Reacting promptly and effectively to wind variations is crucial for them, not only for maintaining optimal speed but also for tactical reasons. Deciding when to change course, is a significant tactical decision that can grant advantage over the competitors.

Similarly, cruisers also acknowledge the importance of wind and course. For them, understanding wind patterns is key to planning their voyage, ensuring safety, and optimizing their route.

The unanimous emphasis on wind and course by all sailors highlights their universal significance in sailing. It suggests that Augmented Reality applications intended for sailors should prioritize providing intuitive and effective ways to monitor and respond to wind and course-related information.

3.3 Personas

Introduction

Drawing from the findings of the interviews, three fictional personas were created: *The Beginner, the Racer,* and *the Ocean Sailor*. These personas are designed to represent the different characteristics and intentions in the sailing community observed among the interview participants.

3.3.1 The Beginner

Portrait

Figure 12: AI generated Portrait of Laura Dekker[9]

Demographics

Name: Laura Dekker
Age: 23
Occupation: Student in Landscape Architecture

Background

Laura is a first-year landscape architecture student at the OST who likes to be outside and enjoys nature. For her studies, she moved to Rapperswil and first has to build up a new circle of friends. She joined the university sailing club to connect with fellow students and try something new. The club organises sailing courses every semester and she has registered for the beginner course. Sailing is taught on small dinghies that are operated alone.

Sailing Experience

After four training sessions in the beginner course, Laura has grasped the principles behind basic maneuvers like tacking and jibing. The practical application, particularly handling and steering with the tiller, remains a persistent challenge for her. She has not yet fully understood the connection between wind direction and the navigable course of the sailboat. Additionally, she faces challenges in low wind, struggling to discern its direction. Strong winds pose a greater challenge, often resulting in capsizing. Understanding the optimal sail position remains a puzzle for her.

[9] https://thispersondoesnotexist.com/

3.3.2 The Racer

Portrait

Figure 13: AI generated Portrait of Sebastian Elcano[10]

Demographics

Name	Sebastian Elcano
Age:	36
Occupation:	Professional Sailor

Background

Sebastian has been sailing since he was a child. His parents owned a boat and were passionate recreational sailors. In his childhood the family spent a lot of time on the water. As a teenager he joined the sailing club and started sailing in regattas. His passion for the sport has driven him to the top echelons of competitive racing. Now he earns his money as a professional sailor.

Sailing Experience

Over the years Sebastian has developed an exceptional proficiency in boat handling. He effortlessly maneuvers through various conditions. To be successful at the top of the world, the boat adjustments are a matter of a few millimeters. Tactic plays an important role. In split seconds he must make descisions.

[10] https://thispersondoesnotexist.com/

3.3.3 The Ocean Sailor

Portrait

Figure 14: AI generated Portrait of Lisa Blair[11]

Demographics	Name	Lisa Blair
	Age:	47
	Occupation:	Architect

Background

Lisa is a 47 year old architect living in Switzerland. Despite being from a landlocked country, Lisa has developed a love for the sea. Every year she spends her vacations on a sailing yacht. Living on the boat with friends and family.

Sailing Experience

Lisa holds the swiss ocean license, allowing her to charter and skipper yachts. She has profound knowledge in navigation and crew handling. Safety is a major concern of her. She can handle the boat and sail, but performance isn't that important to her.

[11] https://thispersondoesnotexist.com/

4 Scenarios

Preamble

In this chapter, a detailed exploration of the primary conceptual scenario *Sailing Course Assistant* is presented, showcasing a promising application of Augmented Reality in sailing. This scenario has been selected due to its comprehensive alignment with the needs and characteristics identified in the personas from the user study. It is laying the foundation for the *Architecture* chapter, where the hardware components and considerations for future implementation are discussed.

Furthermore, six additional scenarios are introduced, each developed based on the research findings and the personas. These scenarios further explore various potential applications of Augmented Reality in sailing

4.1 Sailing Course Assistant

Foundation

The *Sailing Course Assistant* scenario was chosen for detailed elaboration based on key findings from the research and user study. A significant theme emerging from the interview responses was the importance of wind direction and the resulting navigable courses. This scenario builds upon existing application proposals identified during the research but introduces a novel feature by also visualizing the “No Sail Zones”.

The *Sailing Course Assistant* effectively addresses the needs of all three personas identified in the user study:

- **The Beginner** often struggles to understand the connection between wind direction, navigable courses and sail position. In low-wind conditions, it can be particularly challenging to discern from which direction the wind is coming. This Augmented Reality application aims to enhance their learning and sailing experience.
- **The Racer** is required to constantly monitor and react to changes in the wind. By visualizing the wind direction and optimal course, the Augmented Reality application can significantly reduce cognitive load, enabling a greater focus on tactics and competition strategies.
- **The Ocean Sailor** while not primarily focused on performance, still aims to optimize the sailing experience by choosing the most efficient courses.

Description

The *Sailing Course Assistant* scenario provides the following visual aids to enhance the sailing experience:

- **Wind Direction** This feature influences the navigable courses and the optimal sail trim.
- **No Sail Zones** These are areas where sailing is not feasible due to prevailing wind conditions. They cover an area with an angle of around 40° to 45° on either side of the wind direction.

The visual aids are displayed in the sky, centered around the mast. By projecting the information above the usual line of sight, it avoids obstructing the critical view of the water ahead. This design ensures that sailors have a clear view of other boats, obstacles, and the patterns of wind and current on the water surface.

Figure 15 presents a design sketch, illustrating how the *Sailing Course Assistant* scenario could be implemented in a real sailing context. It shows the wind direction with a blue line and the “No Sail Zones” as orange areas. It is providing a visual representation of how these elements would appear to a sailor using the application.

Figure 15: Design sketch of the scenario “Sailing Course Assistant”. Visualizing wind direction (blue line) and the “No Sailing Zones” (orange area).[12]

[12] https://www.pinterest.at/pin/467811480044097262/

4.2 Additional Developed Scenarios

Introduction

In addition to the *Sailing Course Assistant* scenario, six other conceptual scenarios have been developed throughout this thesis. Although these scenarios are not explored in depth within this document, they each represent a unique potential application of Augmented Reality in sailing

4.2.1 Scenario 1: Laera "Screen-stabilized AR 2D interface"

Targeted Persona

- The Ocean Sailor
- The Racer

Displayed Information

- Wind speed
- Wind direction
- Compass
- Water depth

Description

This scenario builds on the interface proposal from Laera et al. [5], more described in the *Research* chapter. The information are displayed in numerical form or as graphs, like in conventional 2D sailing instruments.

4.2.2 Scenario 2: Laera "Body-stabilized AR 3D interface"

Targeted Persona

- The Beginner

Displayed Information

- Wind direction
- Compass
- Course
- Sea currents
- Water depth
- Seabed topology

Description

This scenario builds on the interface proposal from Laera et al. [5], more described in the *Research* chapter. The information are displayed as a 3D boat avatar tied to the users hand that is aligned with the real boats orientation.

4.2.3 Scenario 3: Laera "Boat-stabilized AR 3D interface"

Targeted Persona
- The Ocean Sailor
- The Racer

Displayed Information
- Wind direction
- Compass
- Course
- Sea currents
- Waypoints
- Obstacles

Description
This scenario builds on the interface proposal from Laera et al. [5], more described in the *Research* chapter. The information is placed in the surrounding environment using graphics centered around the boats mast.

4.2.4 Scenario 4: Sail Trim Assistant

Targeted Persona
- The Beginner
- The Ocean Sailor

Displayed Information
- Wind direction and speed
- Optimal sail position

Description
The *Sail Trim Assistant* visually helps users to achieve the optimal sail trim based on the wind direction.

4.2.5 Scenario 5: Sitting Position Assistant

Targeted Persona
- The Beginner
- The Racer

Displayed Information
- Boat position in water
- Optimal sitting position

Description
The *Sitting Position Assistant* visually helps users to find the perfect sitting position, for achieving an optimal weight distribution on the boat and optimal performance.

4.2.6 Scenario 6: Points of Interest Visualizer

Targeted Persona	• The Ocean Sailor • The Racer
Displayed Information	• Waypoints • Obstacles • Chart information
Description	The *Points of Interest Visualizer* integrates information from sea maps into the real-world view or highlights important objects in the surroundings. Including waypoints for navigation, landmarks such as ports or lighthouses and potential hazards like shallows, obstacles, or other vessels approaching.

5 Architecture

Preamble

This chapter proposes an architecture for the hardware components for the implementation of the *Sailing Course Assistant* scenario. First an overview of all components is presented and further each component is more detailed discussed. This includes the technical feasibility and potential integration with existing sailing equipment.

5.1 Hardware Components Overview

Components

In this section, the hardware components of the Augmented Reality application are presented. The system consists of the following components:

- **Wind Sensor:** This device is responsible for measuring the wind direction.
- **Gateway:** The gateway acts as a central hub, receiving data from the wind sensor. It processes and prepares this data for display on the Augmented reality dispaly. The gateway's design allows for future expansion, enabling the addition of more sensors to enhance the application's functionalities.
- **Augmented Reality Display:** This is the interface where users interact with the application. It visually displays the wind direction and the "No Sail Zones", integrated into the user's environment.

Regarding connectivity, the wind sensor is wired to the gateway to ensure stable data transmission. The connection between the gateway and the Augmented Reality display is wireless, allowing for greater flexibility and ease of movement for the user.

Figure 16 illustrates the layout of the system, showing the connections between the wind sensor, gateway, and Augmented Reality display.

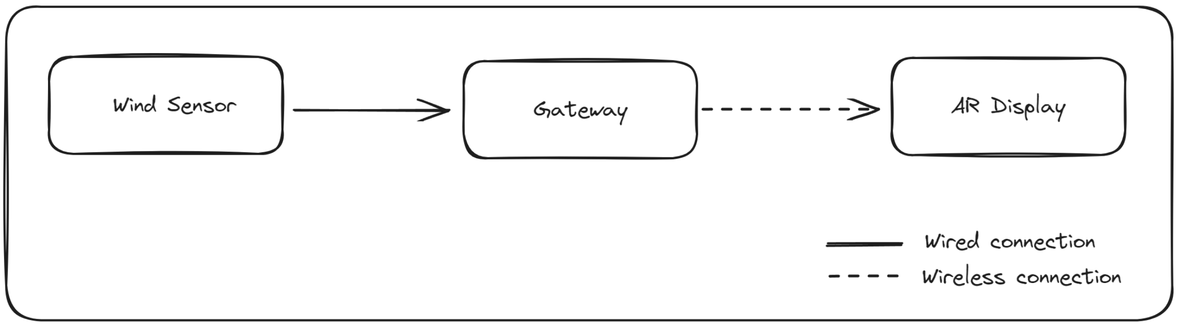


Figure 16: Proposed hardware component diagram for the implementation of the Sailing Course Assisant

Open Source Projects

In the realm of marine software and hardware development, a community is actively engaged in creating and sharing boat projects online[13]. These projects are often made open source and can be used for the implementation of the *Sailing Course Assistant* scenario.

Two open source projects are particularly notable for their applicability:

- **Signal K Platform**[14] The Signal K Data Standard is a modern, open data format tailored for marine use. Built on standard web technologies like JSON, WebSockets, and HTTP, it is both universally accessible and adaptable. Designed to work with common marine hardware, Signal K also offers a server solution for the Raspberry Pi that can connect to marine sensors. For the implementation of the Augmented Reality application, the Signal K server on a Raspberry Pi could serve as the gateway, using its data format to facilitate communication between the gateway and the Augmented Reality Display.
- **DIY Wind Sensor**[15] This project offers instructions for creating a cost-effective wind sensor suitable for sailing applications, using a 3D printer. It includes comprehensive instructions and resources, presenting a budget-friendly alternative to purchasing expensive wind sensors. For the implementation of the Augmented Reality application, the DIY Wind Sensor provides an economical solution to obtain essential wind direction.

Hardware Parts

For the implementation of the Augmented Reality application, specific hardware parts are essential. These parts are listed in *Table 2* . This table also serves as a convenient checklist for acquiring all necessary elements before starting a future implementation and estimates the prices for purchasing the parts.

Part	Component	Estimated Price
Microsoft HoloLens 2	AR Display	€ 3′849
Waterproof HoloLens Caseing	AR Display	unavailable
3D printed Wind Sensor	Wind Sensor	<= € 250
Raspberry Pi	Gateway	€ 40
Waterproof Raspberry Pi Caseing	Gateway	€ 70
Cables	Communication	€ 20

Table 2: Essential hardware parts for the implementation of the Sailing Course Assisant

[13] https://open-boat-projects.org/en/
[14] https://signalk.org/index.html
[15] https://open-boat-projects.org/en/diy-windsensor/

5.2 Augmented Reality Display

Microsoft HoloLens

For the implementation of our Augmented Reality application, a head-mounted display (HMD) is the most practical option. An HMD, like the Microsoft HoloLens 2, allows for hands-free operation, crucial for managing the controls of a boat. Unlike statically mounted video see-through displays, which offer no significant advantage over existing boat instruments, an HMD doesn't require the user to translate information from a 2D display into the real world.

As the literature research revealed, there are currently no Augmented Reality head-mounted display on the market that fully meets the requirements for sailing. However, the Microsoft HoloLens 2 stands out with its numerous features and widespread adoption. Therefore, the decision has been made to use the HoloLens for the further planning of the architecture.

Figure 17 is illustrating a Micosoft HoloLens 2 worn by a person.

Figure 17: Microsoft HoloLens 2 worn by a person[16]

Unity

For developing Augmented Reality applications, referred to as holograms within the HoloLens ecosystem, the Unity platform is a suitable choice[17]. Applications built with Unity are also compatible with other Augmented Reality displays, offering flexibility in development. For instance, smartphones, which often have better waterproofing, can be used during the development phase. Moreover, when a waterproof Augmented Reality HMD suitable for sailing becomes available, the developed application can be easily adapted to run on it.

[16] https://www.microsoft.com/en-us/industry/blog/manufacturing-and-mobility/2019/06/17/workforce-transformation-in-the-intelligent-manufacturing-era/
[17] https://unity.com/unity/features/ar

Moving Platform Mode

The HoloLens needs to track its position in six degrees of freedom to display stable holograms. X, Y, and Z translation, along with roll, pitch, and yaw rotation.

This is achieved by combining information from these two sources:

1. **Visible light cameras** to track the environment. For example, the physical room in which the HoloLens is used.
2. **Inertial Measurement Unit (IMU)** consisting of an accelerometer, gyroscope, and magnetometer to track motion and orientation relative to Earth.

However, for accurate tracking, the environment needs to be stationary relative to earh. On a moving platform, like a sailboat, tracking errors can lead to distorted holograms or loss of tracking. Similar to humans when actual and expected motion are not matching, the HoloLens is getting “motion sick”.

Recognizing this challenge, Microsoft introduced the Moving Platform Mode (MPM)[18] in 2022. MPM adjusts the HoloLens to expect variations in sensor inputs, acknowledging that perfect sensor agreement is unlikely in a moving environment. While Microsoft has tested MPM on small boats, they note that it is currently optimized for large marine vessels experiencing low-dynamic motion. Whether the HoloLens can effectively operate on smaller sailing vessels remains to be tested.

Orientation

For accurate display of information, the HoloLens requires knowledge of its position relative to the boat. The wind sensor determines the wind direction as an angle to the boat’s longitudinal axis, making it essential for the HoloLens to also align with the boat’s axis. Furthermore, the objective is to present the information relative to the boat, centering the hologram at the boat’s mast.

A potential solution for establishing this orientation involves the use of QR codes. These QR codes could be placed on the mast, allowing the HoloLens to recognize them through its camera and thus determine its relative position. However, the effectiveness of this approach in real-world conditions remains to be tested.

Sunlight

When considering the use of the HoloLens in an outdoor environment, there are important factors to take into account, given that the device is primarily designed for indoor use. Two major considerations arise for its outdoor application:

1. **Display Visibility:** It’s crucial to determine whether the display of Augmented Reality content is visible in bright sunlight. Since the HoloLens is not originally optimized for high-light conditions, the clarity and visibility of the holographic display under direct sunlight need to be thoroughly tested.

2. **Camera Functionality for Orientation:** Another significant aspect is the capability of the HoloLens cameras to capture QR codes in outdoor lighting conditions. The effectiveness of the cameras in bright light must be evaluated to ensure accurate positioning and display of the Augmented Reality content.

[18] https://learn.microsoft.com/en-us/hololens/hololens2-moving-platform

5.3 Wind Sensor

Wind Sensor

For the implementation of the *Sailing Course Assistant* scenario, a wind sensor is required to measure the wind direction. These sensors are commonly installed on sailboats, usually at the top of the mast.

Figure 18 is illustrating two types of wind measurement devices: on the left, a wind vane, which visually indicates the direction of the wind, and on the right, a digital wind sensor. The digital wind sensor is able to transmit the measured information digitally. For the implementation of the scenario a digital wind sensor is required.

Figure 18: Wind vane (left) and wind sensor (right) mounted on top of the mast of a sail boat[19]

5.4 Gateway

Gateway

The wind sensor cannot be connected directly to the HoloLens. Instead, a gateway is required to bridge the sensor and the Augmented Reality display. This gateway processes the wind information, including calculating the “No Sail Zones” displayed in the application, and then transmits the processed data to the HoloLens. This setup not only facilitates the current functionality but also allows for the integration of additional sensors in the future, enhancing the application’s capabilities.

Communication

For safety and convenience, the transmission from the gateway to the HoloLens should be wireless, avoiding any hindrance or danger to the user. The HoloLens is equipped with Bluetooth or Wi-Fi modules, which can be utilized for this wireless communication.

[19] https://www.cruisersforum.com/forums/f13/wind-vane-on-front-of-boat-230923.html

6 Conclusion

Preamble

In this chapter the results of this thesis are discussed and suggestions for future development of Augmented Reality applications in the sailing context are presented.

6.1 Discussion on Results

Achievements

This thesis has accomplished several advances in the application of Augmented Reality applications in sailing.

The literature research established the validity and potential of Augmented Reality in enhancing the sailing experience.

Five interviews with a diverse group of sailors analyzed the challenges and needs of the sailing community. They provided insights into the practical aspects of sailing and formed a solid foundation for the development of three personas.

Seven scenarios were developed, four of which are entirely new innovations. These scenarios represent a diverse range of applications, each designed to address specific challenges identified in the research and the interviews.

The most promising scenario was selected and a detailed architecture for the hardware components was created. Laying the foundation for future implementation of this Augmented Reality application.

Design and Implementation

Contrary to the original assumptions made in the project brief, the thesis did not progress to the design and implementation of a prototype. The focus shifted towards research, as more studies were discovered than initially anticipated. The evaluation of the research material was deemed more valuable at this stage of the thesis.

Additionally, the nature of working individually on this project imposed certain limitations. The amount of work that could be realistically achieved alone would not have been enough to build a satisfactory prototype. This also contributed to the decision to focus on the research.

As a result, this thesis forms a theoretical basis for the development of Augmented Reality applications in sailing. It lays the groundwork for future projects, where the insights gathered can be implemented into functional solutions.

6.2 Recommendations

AR Technology

This thesis has found several considerations regarding the current state of Augmented Reality technology being used in maritime environments. The primary challenges identified are durability and waterproofing capabilities.

It is recommended to closely monitor ongoing advancements in Augmented Reality technology. The field is evolving, and future developments could address the maritime-specific challenges more effectively.

In the meantime, exploring interim solutions or adaptations that can bridge the gap is advisable. This could involve developing protective casings and modifications to enhance durability. Such interim solutions would not only provide immediate benefits to the sailing community but also offer valuable insights and experiences that can inform the development of future, more advanced Augmented Reality systems suited for maritime conditions.

HoloLens Field Test

In addition to the fact that the HoloLens is not suitable for maritime environments, there are other questions about its usability that warrant exploration. It is recommended to conduct a field test to evaluate the following aspects:

- **Functionality of the Moving Platform Mode on a Sailboat** This aims to determine whether the HoloLens can effectively track the environment on a moving sailboat and accurately display holograms.
- **Alignment with the Boat's Axis** This test aims to determine if the HoloLens can align itself with the boat's axis using its onboard cameras or if additional external sensors are necessary for precise positioning.
- **Outdoor Performance in Sunlight** This test aims to determine if the HoloLens is usable in outdoor sunlight conditions. It consists of two parts: firstly, assessing whether the holograms remain visible in bright light conditions, and secondly, evaluating if the cameras can effectively capture information under such lighting conditions.

Due to the HoloLens's limitations in maritime settings and restricted access to a sailboat during winter conditions, the field test could not be carried out within the timeframe of this thesis. Therefore, these aspects remain to be tested under appropriate environmental conditions in future development phases.

Next Steps *Sailing Course Assistant*

As the next step in the further development of the *Sailing Course Assistant*, it is suggested to create a design prototype. Employing a human-centered approach is highly recommended to ensure the prototype addresses the needs of the sailing community and an optimal user experience is achieved. This involves actively engaging with sailors to gather their insights and feedback.

7 Project Management

Preamble

In this chapter, the project management strategies and tools employed during this thesis are outlined. It covers the planning, risk management, and quality assurance methods that were deployed.

7.1 Project Planning

Introduction

In this section the organizing and structuring the thesis are detailed. Covered are the methodology, the tools utilized for planning and execution, and the delineation of project phases and milestones. Additionally, the implementation of Scrum and time tracking are discussed.

7.1.1 Method

Scrum+

In this project Scrum+ was employed, a hybrid approach blending elements of Scrum and the Rational Unified Process (RUP). From RUP, the concept of dividing the project into distinct phases was adopted, providing a structured framework for the entire project timeline. For more immediate and flexible planning, the agile methodologies of Scrum were integrated, particularly through the use of iterative sprints. This combination allowed for both long-term structural clarity and short-term adaptability in the project management.

7.1.2 Tools

Jira

As the primary tool for the project management *Jira* by *Atlassian* was used. It was specifically configured to align with the project's requirements, facilitating effective planning and tracking throughout the project's duration.[20]

Jira Extensions

For a better experience and additional functions in *Jira* the following extensions were integrated:

- **Time Tracking:** For more accurate time tracking, *Timesheet Tracking for Jira* by *TouchDown* was used.[21]
- **Risk Management:** For risk tracking and analysis *Hedge: Risk Management, Risk Register & Risk Matrix for Jira* from *Appfire* was employed.[22]

[20] https://www.atlassian.com/software/jira
[21] https://marketplace.atlassian.com/apps/1216988/timesheet-tracking-for-jira
[22] https://marketplace.atlassian.com/apps/1227408/hedge-risk-management-risk-register-risk-matrix-for-jira

7.1.3 Phases

Epics

The project was initial segmented into rough phases, which were implemented using *Jira* Epics. Six phases were defined to structure the project's timeline and key stages.

Table 3 lists the epics at the project start.

Phase	Duration	Description
Project Setup	2 Weeks	Setup project management tools and documentation
Analysis	3 Weeks	Conduct literature research and user study
Design	3 Weeks	Develop design prototype
Implementation	3 Weeks	Implement prototype
Evaluation	2 Week	Collect user feedback and evaluate prototype
Project Completion	1 Week	Complete documentation and submission

Table 3: Planned project phases at project start

Figure 19 presents a screenshot of the *Jira* timeline captured at the start of the project, illustrating how these phases were organized and visualized within the tool.

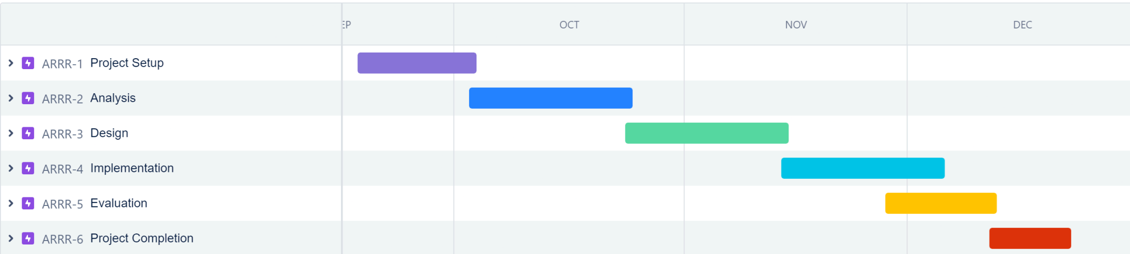


Figure 19: Screenshot Jira *timeline. Planned project phases at the beginning of the project*

Reorganization

During the project, the focus of the thesis shifted. More studies were found during the literature research than initially anticipated, leading to a greater emphasis and extension of the analysis phase. This shift resulted in the development of a prototype not being feasible within the project timeline. Given that the project was also a solo endeavor, the available time was limited, and developing a prototype of satisfactory was not achievable.

For these reasons, the focus was redirected towards architecture. Determining what data would be needed to implement the scenario, which hardware components to use, and how these components would communicate with each other. Furthermore, it became apparent that writing this document required more time than initially expected.

To accommodate these changes, the project was reorganized. The analysis phase was extended. The design,implementation and evaluation phases were removed, and a new phase dedicated to architecture was introduced. Additionally, the project completion phase was extended to allow for more focus on documentation.

Table 4 illustrates the project phases as they were actually carried out.

Phase	Duration	Description
Project Setup	2 Weeks	Setup project management tools and documentation
Analysis	6 Weeks	Conduct literature research and user study
Architecture	2 Weeks	Developing a hardware for future implementaion
Project Completion	4 Week	Complete documentation and submission

Table 4: Actual project phases carried out

Figure 20 presents a screenshot of the *Jira* timeline captured at the end of the project, illustrating how these phases were organized and visualized within the tool.

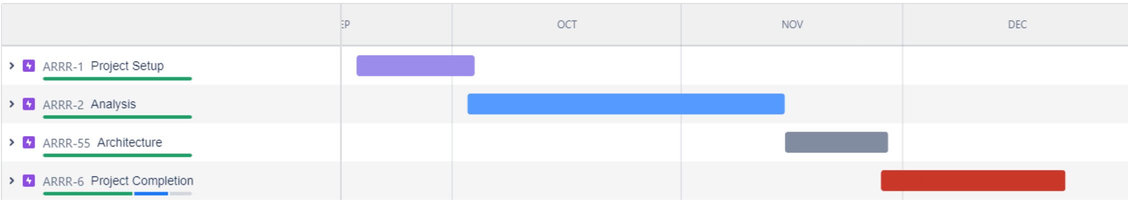


Figure 20: Screenshot Jira *timeline. Actual carried out project phases*

7.1.4 Milestones

Introduction Milestones are significant markers that denote critical achievements and points of progress in a project's timeline. For this project, a milestone was defined at the end of each phase. Since Jira does not offer a native functionality for creating milestones, a new issue type was specifically created for this purpose. Similar to work tasks, these milestones were initially placed in the backlog and then added to sprints as the project progressed. They serve not only as goals to strive for but also as opportunities to evaluate the project's direction and success at various stages.

7.1.4.1 M1: End of Project Setup

Due date: 03.10.2023

Acceptance Criterias:

- Project management tool set up
- Project time tracking tool set up
- Project documentation document set up
- Automated CI to publish project documentation
- Automated CI to publish meeting minutes
- Project plan: How, when and who will work on the project?
- Risks: What can endager the project and how to handle it?
- Quality assurance: How is a good quality of the project ensured?

Actual achieved: 10.10.2023

Reflection: At the time of due date the acceptance criterias were not all fullfilled. Therefore the project setup was extended for another week. The impact on the overall project was considered uncritical, so the project planning was not adjusted. At the time of the achievement of the milestone, the documentation was not as extensive as intended. However, this was considered as not important for the next steps and the next project phase was started.

7.1.4.2 M2: End of Analysis

Due date: 24.10.2023

Acceptance Criterias:

- Literature research: What is the current scientific state of AR systems in the context of sailing.
- Interviews: What are problems while sailing? Understanding and determining the usage context and requirements talking to sailors.
- Personas: Describe fictional personas that could use the application based on interviews.
- Scenarios: Describe scenarios that could be implemented based on research and interviews.
- Scenario chosen for prototype implementation

Actual achieved: 14.11.2023

Reflection: With the extension of the analysis phase, this milestone was also postponed by 3 weeks. Some results of the analysis in the acceptance criterias were not documented pronounced at the end of the phase. This was taken into account by extending the project completion phase. To finish the documentation at the end of the project.

7.1.4.3 M3: End of Desing

Due date: 14.11.2023

Acceptance Criterias:
- Design solutions for the prototype developed
- User feedback collected and into design integrated

Actual achieved: -

Reflection: This milestone was removed with the corresponding design phase

7.1.4.4 M4: End of Implementation

Due date: 05.12.2023

Acceptance Criterias:
- Prototype implemented
- Prototype fulfills requirements from analysis
- User feedback from evaluation integrated

Actual achieved: -

Reflection: This milestone was removed with the corresponding implementation phase

7.1.4.5 M5: End of Evaluation

Due date: 12.12.2023

Acceptance Criterias: User feedback on prototype collected

Actual achieved: -

Reflection: This milestone was removed with the corresponding evaluation phase

7.1.4.6 M6: Project Finish

Due date: 22.12.2023

Acceptance Criterias:
- Documentation complete
- All relevant elements submitted on time

Actual achieved: 22.12.2023

Reflection: At the time of writing this, I hope to reach this milestone. If not, I think I have more to worry about than this text. Therefore, milstone exceedingly well fulfilled

7.1.4.7 M7: End of Architecture

Due date: 28.11.2023

Acceptance Criterias:	• Technical feasability for one scenario is discussed • What data is needed for the implementation of the scenario • What hardware components are needed for the implementation of the scenario • Who does the communication between the components work
Actual achieved:	28.11.2023
Reflection:	This mileston was new introduced after the reorganization of the project phases marking the end of the architecture phase. The acceptance critearias were mostly fullfield at the time of the due date. Missing were some parts in the documentation. As the next phase was dedicated to the writing of the documentation, there were no concerns to start with the project completion phase.

7.1.5 Scrum Elements

Introduction

In this section the applied scrum elements are decribed.

Sprint

The work is completed in two-week sprints. Each sprint has a sprint goal and some sprint increments, small steps towards the final project product.

During the ongoing sprint the tasks were managed using the *jira* sprint board. In four swimlane the progress of the tasks is visualized.

These swimlanes were used:
- **To Do** For tasks that have not yet been started
- **In Progress** For tasks that are currently being worked on
- **Review** For tasks waiting for a review from the advisor
- **Done** For tasks that are done

Backlog Refinement

In the backlog refinement new tasks were created in the backlog and the time for completion was estimated.

Sprint Planning

Before each sprint start, the sprint was filled with tasks from the backlog so that the estimated time of work was 2 weeks and a sprint goal was defined.

Sprint Review

At the end of each sprint, the outcome of the Sprint was inspected and future adaptations were determinated. The Sprint review took place in the weekly meeting with the supervisior.

Daily Scrum Meeting

Since the project team only consists of one person, no daily Scrum meetings were held.

Weekly Meeting with Supervisior

Every week a meeting with the project supervisor took place.

7.1.6 Time Tracking

Time Expenditure

This thesis is worth 8 ects credits, each credit is valued with 30 hours of work. This results in a total workload of 240 hours. Distributed over the 14 weeks of the semester a working time of approximately 17 hours or 2 days is targeted.

Tracking

To ensure that sufficient effort was put into this thesis, hours worked were recorded throughout the semester. In total, 216 hours and 10 minutes were dedicated to the project. This falls within a 10% range of the total 240 hours required, which is an acceptable margin.

7.1.7 Sprints

7.1.7.1 Sprint 1

Period 18.09.2023 - 03.10.2023

Sprint goal Complete project setup

Sprint increments

- Project management tools
- Project documentation
- Chapter project management
- Milestone: Complete project setup

Retrospective

- Sprint goal was not achieved
- Time estimation for documentation too low
- Set up typst took longer
- Writing took longer
- Lots of considerations how to do things

Screenshot Jira

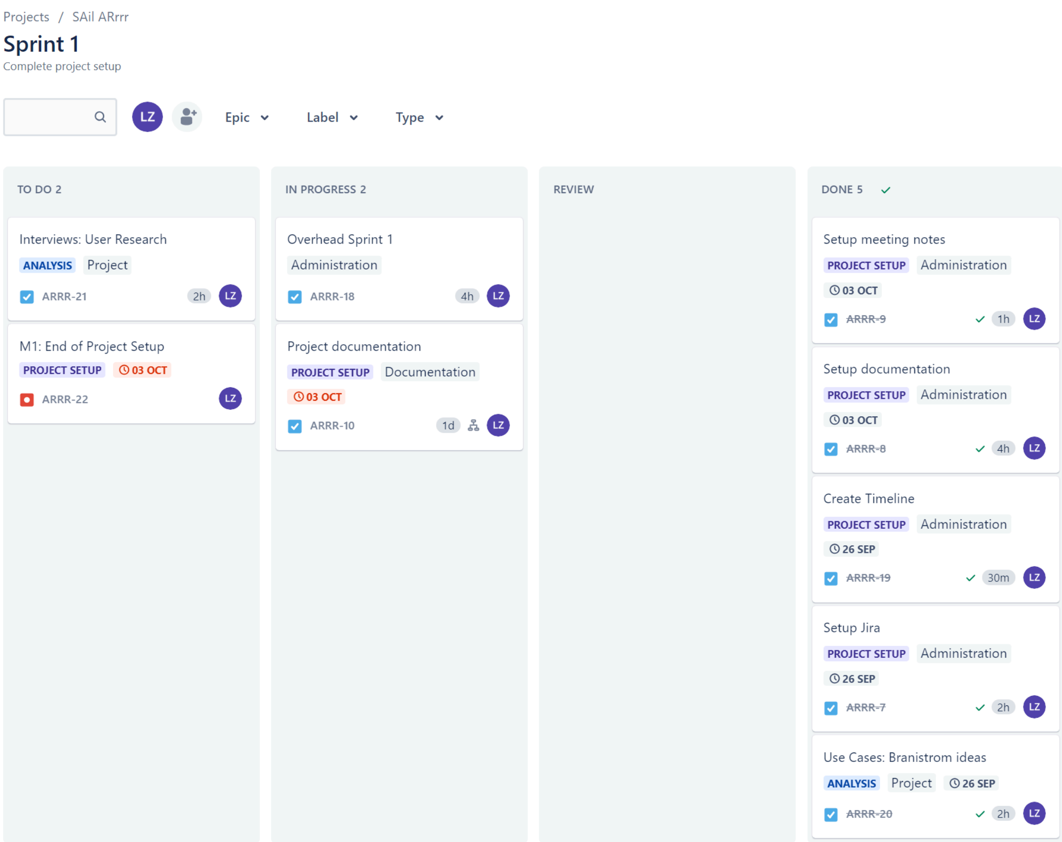


Figure 21: Screenshot of the Jira swimlanes at the end of Sprint 1

7.1.7.2 Sprint 2

Period 03.10.2023 - 17.10.2023

Sprint goal Interviews & Literature Research

Sprint increments

- Interview Guide
- Interview Protocols
- Literature sources

Retrospective

- Sprint goal was not achieved
- Too little time was found, the target hours were not met
- Finishing the documentary was postponed, focus on more outcome
- Many AR-Sailing studies found, focus shift towards research, therefore design phase extended
- Conduct interviews took longer than expected.

Screenshot Jira

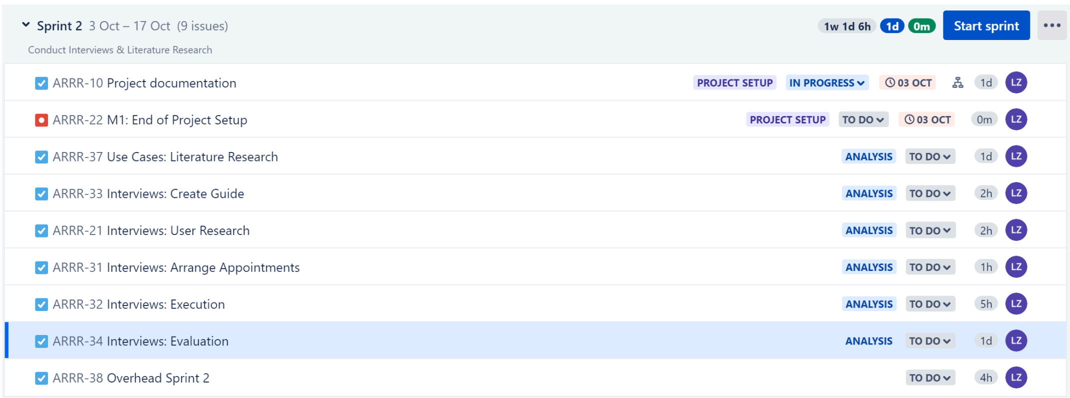


Figure 22: Screenshot of the Jira *tasks at the start of Sprint 2*

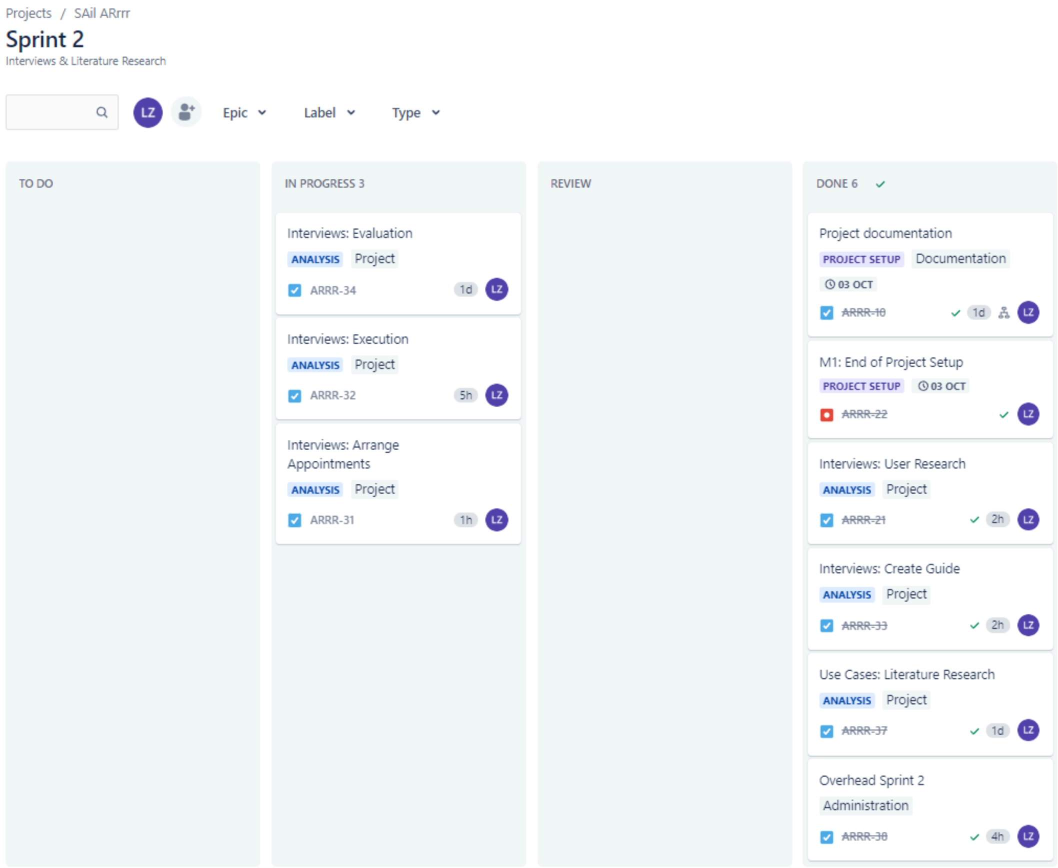


Figure 23: Screenshot of the Jira *swimlanes at the end of Sprint 2*

7.1.7.3 Sprint 3

Period 17.10.2023 - 31.10.2023

Sprint goal Deep dive into the Studies & Interviews

Sprint increments
- Interviews Evaluation
- Literature Summary

Retrospective
- Sprint goal was achieved
- Interviews all done

Screenshot Jira

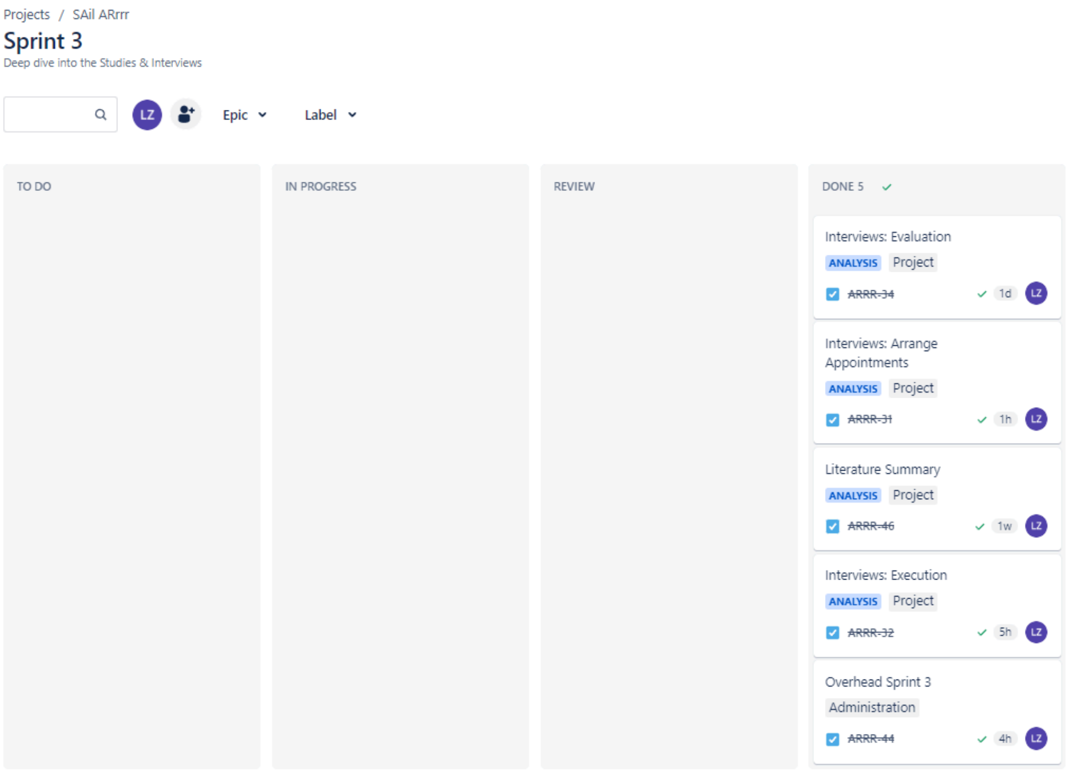


Figure 24: Screenshot of the Jira swimlanes at the end of Sprint 3

7.1.7.4 Sprint 4

Period 31.10.2023 - 15.11.2023

Sprint goal Personas and Scenarios

Sprint increments

- Personas
- Scenarios
- Milestone: End of Analysis

Retrospective

- Sprint goal was not fully achieved
- Reorganisation of the project. Task from Desing phase was not processed
- Milestone not reached
- Documentation of research took longer than expected

Screenshot Jira

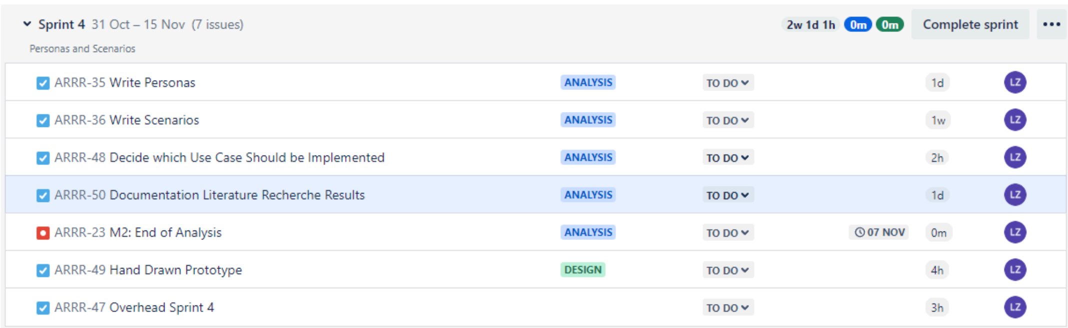


Figure 25: Screenshot of the Jira tasks at the start of Sprint 4

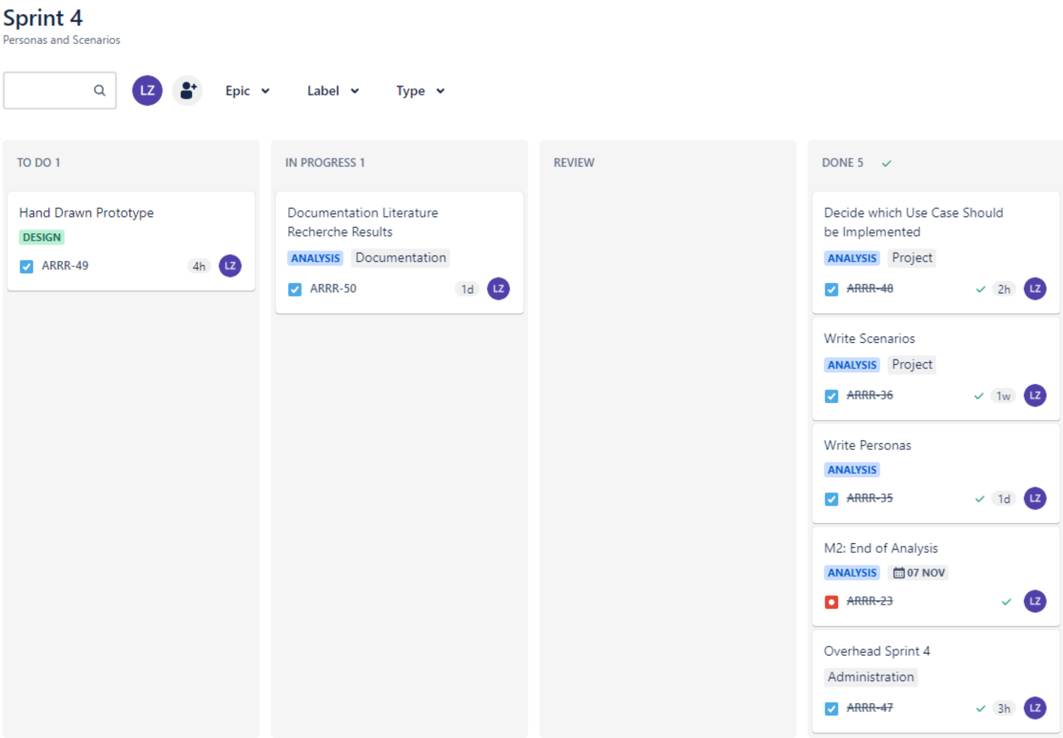


Figure 26: Screenshot of the Jira swimlanes at the end of Sprint 4

7.1.7.5 Sprint 5

Period 15.11.2023 - 29.11.2023

Sprint goal Architecture

Sprint increments

- Architectur
- Milestone: End of Architecure

Retrospective

- Sprint goal was not fully achieved
- Personas done
- Milestone not reached
- Documentation of reserach and scenarios took longer than expected

Screenshot Jira

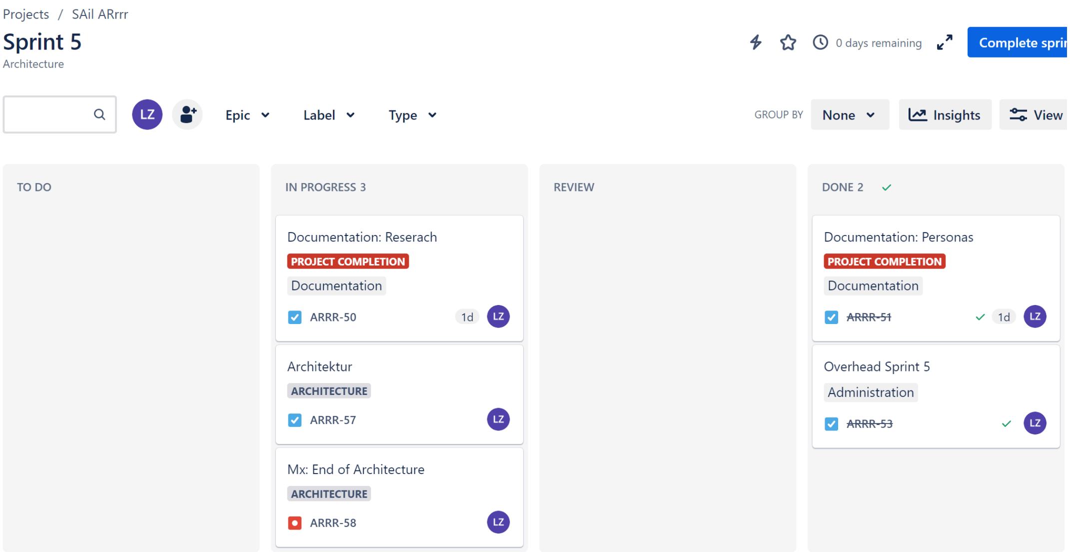


Figure 27: Screenshot of the Jira swimlanes at the end of Sprint 5

7.1.7.6 Sprint 6

Period 29.11.2023 - 13.12.2023

Sprint goal Final push

Sprint increments
- Documentation
- Milestone not reached

Retrospective
- Sprint goal was achieved

Screenshot Jira

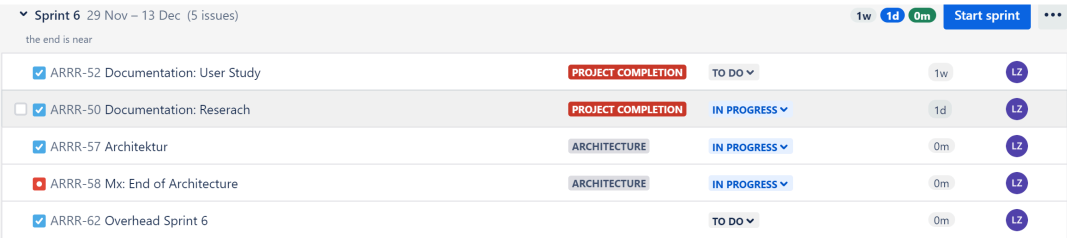


Figure 28: Screenshot of the Jira tasks at the start of Sprint 6

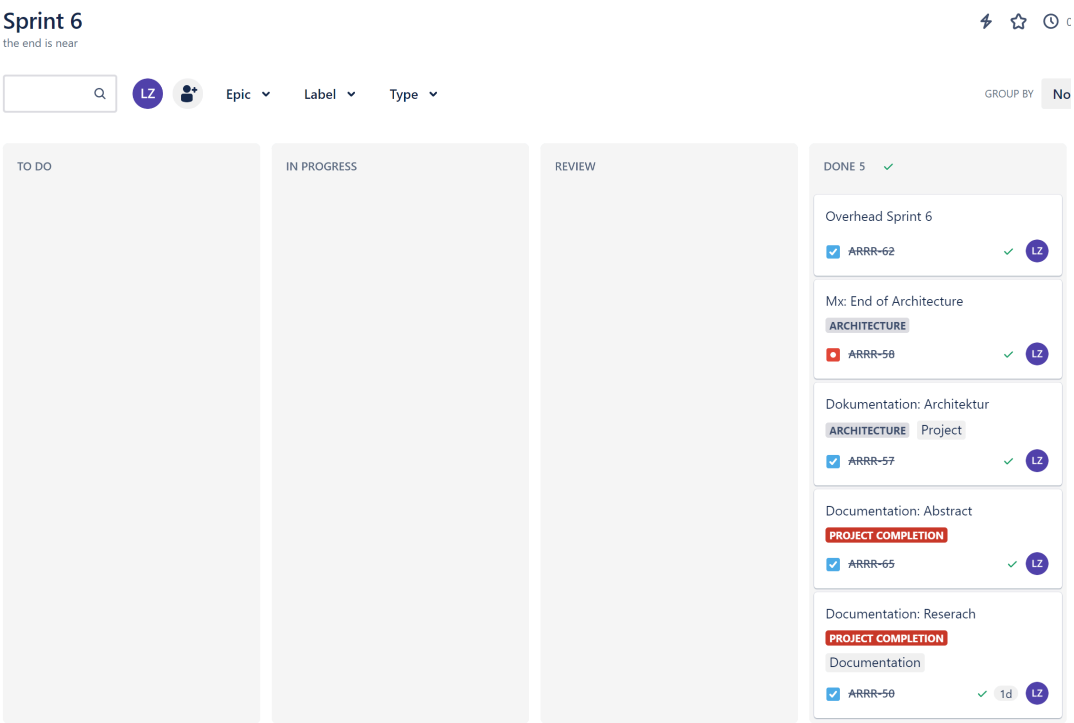


Figure 29: Screenshot of the Jira swimlanes at the end of Sprint 6

7.1.7.7 Sprint 7

Period 13.12.2023 - 22.12.2023

Sprint goal Submission

Sprint increments
- Documentation complete
- Submission

Retrospective
- Sprint goal was achieved

Screenshot Jira

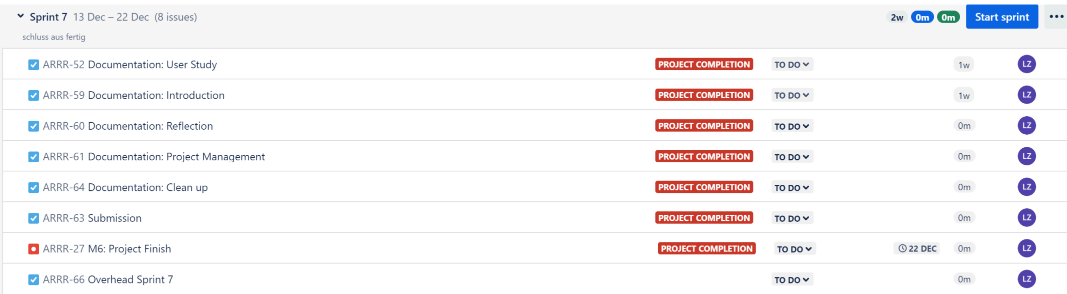


Figure 30: Screenshot of the Jira tasks at the start of Sprint 7

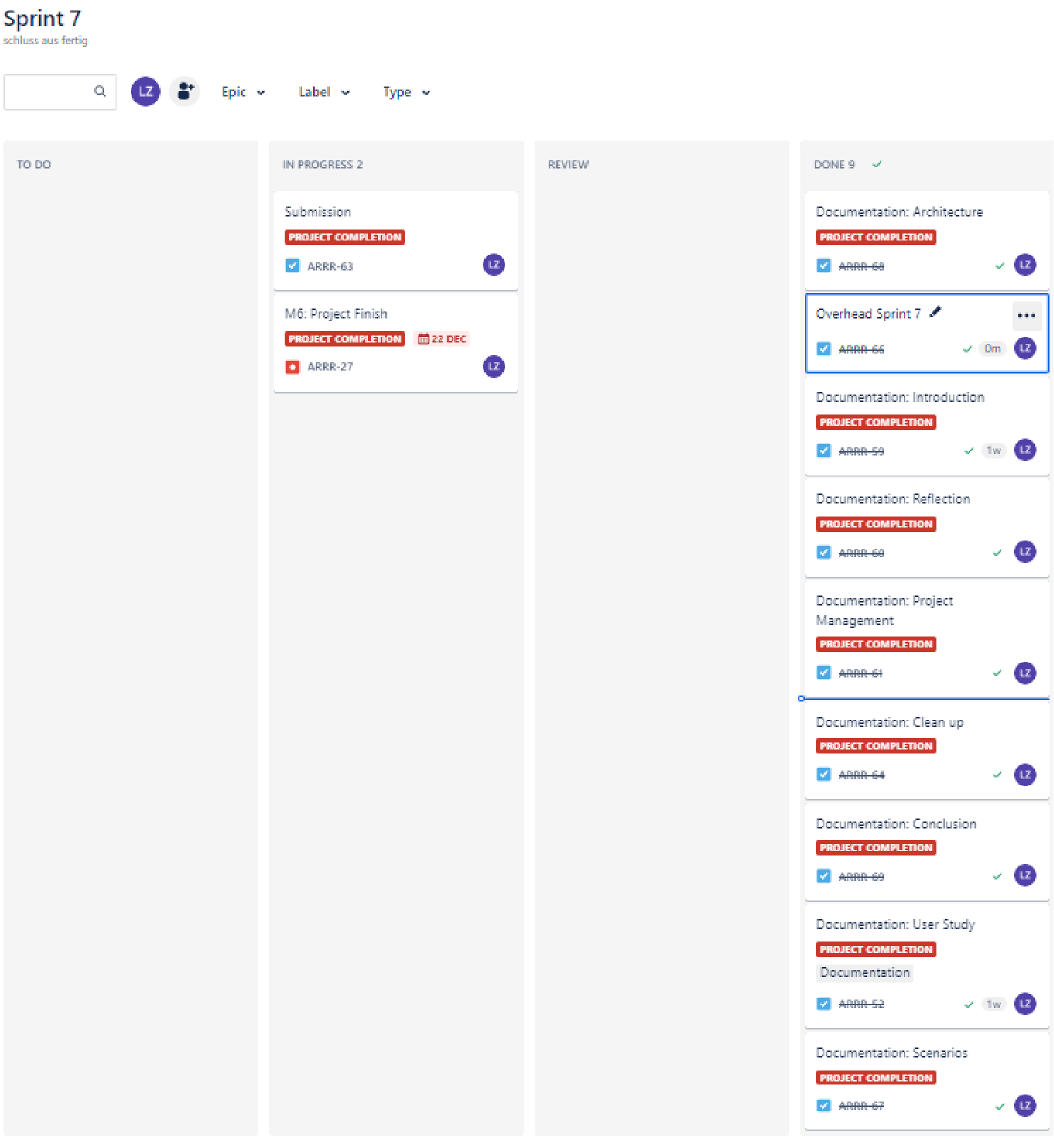


Figure 31: Screenshot of the Jira *swimlanes at the end of Sprint 7*

7.2 Risk Management

Introduction

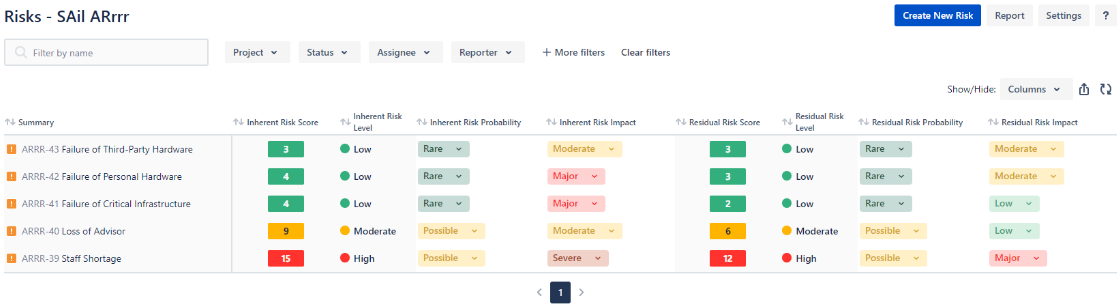
In the section, the strategies employed for managing risks in this project are explored. The risk management involved the identification, analysis, and mitigation of possible risks. The key risks that were identified, along with the analyses conducted and measures developed to manage these risks, are outlined in the following discussion.

7.2.1 Risk Analysis

Introduction

In the risk analysis process, each identified risk is assigned a probability of occurrence and an impact level should it occur. These values are then used to calculate a risk score, which helps in classifying the risk as low, medium, or high according to the risk matrix. This classification is done twice: firstly, to determine the inherent risk level, which is the risk level before any countermeasures are implemented, and secondly, to assess the residual risk level, which is the risk level after the implementation of countermeasures.

Figure 32 presents a screenshot of the *Jira* risks management, illustrating how the risks were organized and visualized within the tool.



Summary	Inherent Risk Score	Inherent Risk Level	Inherent Risk Probability	Inherent Risk Impact	Residual Risk Score	Residual Risk Level	Residual Risk Probability	Residual Risk Impact
ARRR-43 Failure of Third-Party Hardware	3	Low	Rare	Moderate	3	Low	Rare	Moderate
ARRR-42 Failure of Personal Hardware	4	Low	Rare	Major	3	Low	Rare	Moderate
ARRR-41 Failure of Critical Infrastructure	4	Low	Rare	Major	2	Low	Rare	Low
ARRR-40 Loss of Advisor	9	Moderate	Possible	Moderate	6	Moderate	Possible	Low
ARRR-39 Staff Shortage	15	High	Possible	Severe	12	High	Possible	Major

Figure 32: Screenshot of identified risks in Jira

Risk Matrix

Table 5 illustrates the specific values assigned to each risk probability and impact, which are used in calculating the risk score used for the classification of the risk.

Probability	Impact	Value
Rare	Insignificant	1
Unlikely	Low	2
Possible	Moderate	3
Likely	Major	4
Certain	Severe	5

Table 5: Risk matrix to calculate the risk score

Risk Level Formula

The risk level formula is used to calculate the the risk score used for the classification of the risk.

$$\text{risk level} = \text{probability} \cdot \text{impact}$$

Inherent Risks Matrix

The inherent risks matrix provides a visual representation of the potential risks identified, before any mitigating actions are taken. This matrix categorizes risks based on their likelihood of occurrence and the impact they could have if they materialize. It serves for prioritizing risks and planning appropriate countermeasures in the initial stages of the project.

Figure 33 presents a screenshot from *Jira* of the inherent risks matrix, showcasing how each risk is categorized and assessed.

Figure 33: Screenshot of inherent risk matrix in Jira

Residual Risks Matrix

The residual risks matrix provides a visual representation of the potential risks identified, after the implementation of countermeasures. This matrix categorizes risks based on their likelihood of occurrence and the impact they could have if they materialize.

Figure 33 presents a screenshot from *Jira* of the residual risks matrix, showcasing how each risk is categorized.

Figure 34: Screenshot of residual risk matrix in Jira

Results In the risk analysis, five distinct risks were identified. Of these, one was classified as high-risk, one as moderate-risk, and the remaining three as low-risk. Following the implementation of countermeasures, there was a notable reduction in the overall risk levels. While the probability of these risks occurring remained unchanged, the impact of their occurrence was successfully mitigated.

7.2.2 Risks

Inroduction In this section all the identified risks are further detailed.

7.2.2.1 Staff Shortage

Description The author of this thesis is no longer able to work due to illness, accidents or other unforeseen events.

Counter-measures The project documentation is constantly updated and working hours are documented in order to identify the project status at any time and to be able to resume work after an absence.

Actions on Risk Occurrence If the loss of work is only for a short duration a request to postpone the final deadline can be submitted. Otherwise the theseis must be canceled or postponed to another semester.

Risk assessment

Type	Probabiliy	Impact	Level
Inherent	Possible	Severe	High
Residual	Possible	Major	High

Figure 35: Risk assessment of Risk: Staff Shortage

7.2.2.2 Loss of Advisor

Description The advisor of this thesis is no longer able to advise due to illness, accidents or other unforeseen events.

Counter-measures The project documentation is constantly updated and working hours are documented in order to identify the project status at any time and to be able to resume advisement after an absence.

Actions on Risk Occurrence If the loss of advisor is only for a short duration the thesis can be continued independently. Does the absence last longer and no representative advisor takes over, a complaint can be submitted to the academic advisor, the course director or the university management.

Risk assessment

Type	Probabiliy	Impact	Level
Inherent	Possible	Moderate	Moderate
Residual	Possible	Low	Moderate

Figure 36: Risk assessment of Risk: Loss of Advisor

7.2.2.3 Failure of Critical Infrastructure

Description The infrastructure used for writing and implementing this theses, mostly cloud services, can no longer be used.

Counter-measures The probability of this occurring is very low and therefore no explicit countermeasures are taken.

Actions on Risk Occurrence Depending on the failing infrastructure, a solution must be found spontaneously.

Risk assessment

Type	Probabiliy	Impact	Level
Inherent	Rare	Major	Low
Residual	Rare	Low	Low

Figure 37: Risk assessment of Risk: Failure of Critical Infrastructure

7.2.2.4 Failure of Personal Hardware

Description The author's hardware for writing and implementing this thesis breaks or can no longer be used for other reasons.

Counter-measures The probability of this occurring is very low and therefore no explicit countermeasures are taken. The author has household contents insurance which can compensate for damages.

Actions on Risk Occurrence Depending on the failing hardware, a solution must be found spontaneously. As backup the university has hardware that can be used.

Risk assessment

Type	Probabiliy	Impact	Level
Inherent	Rare	Major	Low
Residual	Rare	Moderate	Low

Figure 38: Risk assessment of Risk: Failure of Personal Hardware

7.2.2.5 Failure of Third-Party Hardware

Description Third-Party hardware for writing and implementing this thesis breaks or can no longer be used for other reasons.

Counter-measures The probability of this occurring is very low and therefore no explicit countermeasures are taken. The author has liability insurance which can compensate for damages.

Actions on Risk Occurrence Depending on the failing hardware, a solution must be found spontaneously.

Risk assessment

Type	Probabiliy	Impact	Level
Inherent	Rare	Moderate	Low
Residual	Rare	Moderate	Low

Figure 39: Risk assessment of Risk: Failure of Third-Party Hardware

7.3 Quality Assurance

Introduction

In this section, the various actions undertaken to ensure good quality and safety are described.

Types

This document was written using Types[23].

Github

For the validation of versioning and backups of the document, GitHub was utilized. This platform ensured that all changes and iterations of the project documentation were systematically tracked and securely stored. To further streamline the process, a CI/CD (Continuous Integration/Continuous Deployment) pipeline was implemented. This setup facilitated the automated building of the document.

In the event of any failures or issues in the pipeline, a notification system was established using a Microsoft Teams channel. This integration allowed for immediate alerts from GitHub whenever the pipeline encountered problems, ensuring prompt attention and resolution.

Dashboard

For the distribution of the project's documentation, including the main document, meeting minutes, and essential links, GitHub Pages was employed to create a online project dashboard. This dashboard provided a centralized and accessible location for all project-related materials. This ensured that the most recent versions of the documents were always available, particularly beneficial for the advisor, who could access the latest work at any time.

Figure 40 is showing a screenshot of the project dashboard.

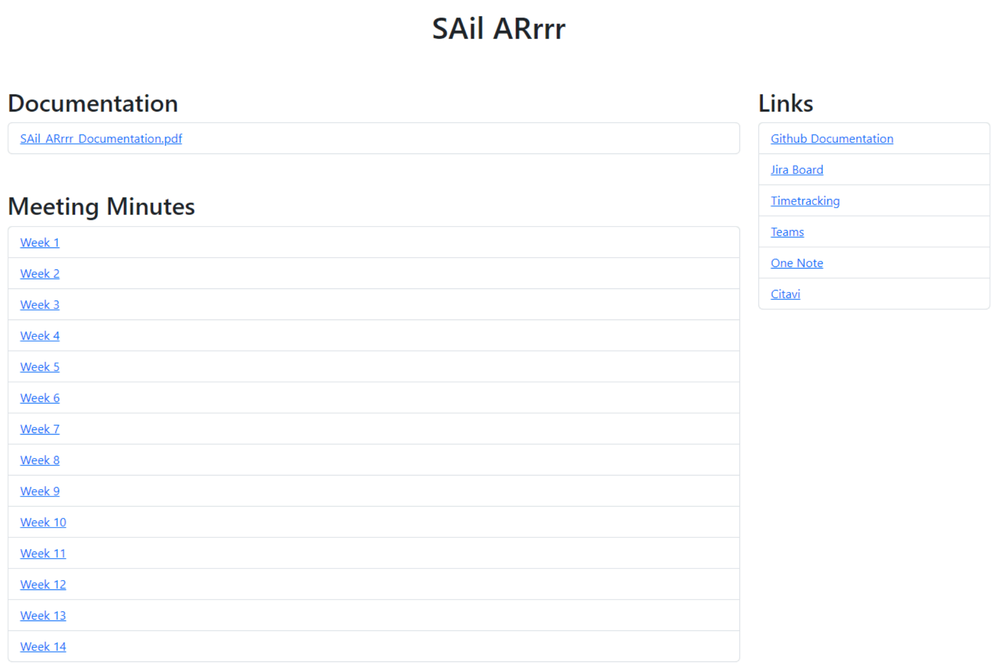


Figure 40: Screenshot of the project dashboard

[23] https://typst.app/

8 Glossary

8.1 Abbreviations

AR Augmented Reality. Further described in the *Research* chapter

HMD Head Mounted Display. Further described in the *Research* chapter

OST Eastern Switzerland University of Applied Sciences *https://www.ost.ch/*

SAil ARrrr Thesis name. A word formation of *SA* (Semester Arbeit), *Sail*, *AR* and the piratey expression *arrr*

YCR Yacht Club Rapperswil *https://www.ycr.ch/*

8.2 Nautical Terms

Bow The bow is the forward part of the hull of a ship or boat, the point that is usually most forward when the vessel is underway.[24]

Jibe Jibe is a sailing maneuver whereby a sailing vessel reaching downwind turns its stern through the wind.[25]

Knot The knot is a unit of speed equal to one nautical mile per hour, exactly 1.852 km/h.[26]

Nautical Mile A nautical mile is a unit of length used in air, marine, and space navigation, and for the definition of territorial waters. Today the international nautical mile is defined as 1,852 metres.[27]

Points of Sail A point of sail is a sailing craft's direction of travel under sail in relation to the true wind direction over the surface.[28]

- *Into the wind* where a sailing craft is pointed directly upwind in the middle of the no-go zone, where sails cannot generate power.
- *Close-hauled* where a craft is sailing, pointed near the no-go zone.
- *Reaching*, including:
  - *Close reach:* between close-hauled and a beam reach.
  - *Beam reach:* the craft has the true wind at a right angle to its direction (on its beam).
  - *Broad reach:* the true wind is coming from behind, but not directly behind.
- *Running downwind* where a craft has the wind coming from directly behind

Port Port refers to the left side of a watercraft, viewed from stern to bow.[29]

Starboard Starboard refers to the right side of a watercraft, viewed from stern to bow.[29]

[24] https://en.wikipedia.org/wiki/Bow_(watercraft)
[25] https://en.wikipedia.org/wiki/Jibe
[26] https://en.wikipedia.org/wiki/Knot_(unit)
[27] https://en.wikipedia.org/wiki/Nautical_mile
[28] https://en.wikipedia.org/wiki/Point_of_sail
[29] https://de.wikipedia.org/wiki/Backbord_und_Steuerbord

Stern The stern is the back or aft-most part of a ship or boat.[30]

Tacking Tacking is a sailing maneuver by which a sailing craft turns its bow toward and through the wind so that the direction from which the wind blows changes from one side of the boat to the other.[31]

[30] https://en.wikipedia.org/wiki/Stern
[31] https://en.wikipedia.org/wiki/Tacking_(sailing)

9 Bibliography

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[4] F. Laera, V. M. Manghisi, A. Evangelista, A. E. Uva, M. M. Foglia, and M. Fiorentino, “Evaluating an augmented reality interface for sailing navigation: a comparative study with a immersive virtual reality simulator”, *Virtual Reality*, vol. 27, no. 2, pp. 929–940, Jun. 2023, doi: 10.1007/s10055-022-00706-7.

[5] F. Laera, A. Evangelista, V. Manghisi, M. Foglia, and M. Fiorentino, “Role-Based Sailing Augmented Reality Interface: Three Proposals for Head-Mounted Display”, in *Advances on Mechanics, Design Engineering and Manufacturing IV*, Cham: Springer International Publishing, 2023, pp. 1305–1315. doi: 10.1007/978-3-031-15928-2_114.

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10 List of Figures

[32] https://en.wikipedia.org/wiki/Point_of_sail
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[35] https://www.ikea.com/de/de/this-is-ikea/corporate-blog/ikea-place-app-augmented-reality-puba55c67c0
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[44] https://www.microsoft.com/en-us/industry/blog/manufacturing-and-mobility/2019/06/17/workforce-transformation-in-the-intelligent-manufacturing-era/
[45] https://www.cruisersforum.com/forums/f13/wind-vane-on-front-of-boat-230923.html

11 List of Tables

12 Appendix

12.1 Initial Project Definition

Einsatz von Augmented Reality zur Visualisierung der Umgebungsbedingungen beim Segeln

Beteiligte Personen

Diese Arbeit wird verfasst von
Laurin Zubler; laurin.zubler@ost.ch

Betreuer dieser Arbeit ist
Prof. Dr.-Ing. Frieder Loch; frieder.loch@ost.ch

Problembeschreibung

Augmented Reality (AR) bietet vielfältige Möglichkeiten in unterschiedlichen Anwendungsbereichen. Die Technologie ermöglicht es, die Realität mit relevanten Informationen zu überlagern. Einsatzmöglichkeiten sind zum Beispiel in der Navigation oder bei der Steuerung von Flugzeugen. Auch das Segeln bietet denkbare Anwendungen, die mit AR unterstützt werden können. So kann beispielsweise die Windrichtung oder der Kurs des Bootes eingeblendet werden. Diese Informationen können die Navigation erleichtern, insbesondere für Segelanfänger.

Formulierung eines konkreten Auftrags

Die Arbeit soll die folgenden Aspekte adressieren. Nach Absprache kann auch im Verlauf der Arbeit vom beschriebenen Auftrag abgewichen werden.

1. **Literaturrecherche.** Es soll eine strukturierte Sammlung von Anwendungsfällen erstellt werden, die mit AR unterstützt werden können. Diese strukturierte Auflistung soll dabei helfen, Anwendungsfälle beim Segeln zu identifizieren und zu strukturieren.
2. **Vergleich der Technologien.** Die identifizierten Anwendungsfälle sollen miteinander verglichen werden, um zu bestimmen, welcher Anwendungsfall umgesetzt werden soll. Hierfür soll ein methodisches Vorgehen entwickelt werden.
3. **Mensch-zentrierte Analyse.** Durch eine menschzentrierte Analyse sollen die Bedürfnisse der verschiedenen Nutzergruppen für den ausgewählten Anwendungsfall erfasst und verstanden werden. Darauf aufbauend soll der konkrete Lösungsansatz entwickelt werden.
4. **Entwicklung eines Lösungsansatzes.** Der identifizierte Lösungsansatz wird entwickelt und iterativ verfeinert (z.B. mit Hilfe von Figma-Prototypen). Hierfür soll nach Möglichkeit Feedback potenzieller Nutzer:innen einbezogen werden.
5. **Prototypische Implementierung und Evaluation.** Der entwickelte Lösungsansatz wird prototypisch implementiert. Eine empirische Evaluation des gewählten Lösungsansatzes wird nach Möglichkeit durchgeführt.
6. **Kritische Reflektion.** Der gewählte Lösungsansatz wird kritisch reflektiert. Möglichkeiten zur iterativen Verbesserung in zukünftigen Projekten werden aufgezeigt.

Umfang und Form der erwarteten Resultate

Die Ergebnisse der Arbeit (Quellcode der Software inkl. Dokumentation, sowie der Projektbericht) werden den Projektbeteiligten zur weiteren Nutzung zur Verfügung gestellt.

Anfangs- und Abgabetermin

- Start der Bearbeitung: **Montag, 18. September 2023**
- Abgabe der SA: **Freitag, 22. Dezember 2023 (17:00 Uhr)**

Zulässige Hilfsmittel und weitere Betreuung

Alle verwendeten Hilfsmittel werden in der Arbeit aufgeführt. Die Betreuung erfolgt durch die genannte Betreuungsperson. Es werden wöchentliche Beratungstermine vereinbart und von den Studierenden protokolliert.