User Interaction in Inflight Entertainment Map Application

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tactel

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Abstract

Inflight Entertainment (IFE) is the system that passengers can interact with during long flights. This includes watching movies, play games and interacting with a map application. Improving the inflight experience of passengers is a constantly evolving process. Many airlines are actively searching for new technologies that could further improve the user experience.

This thesis explores new ways to improve the user experience when interacting with an inflight map application, where passengers can receive information about the current flight route. The focus has been on exploring the suitability of mobile augmented reality in a map application running on the passengers own devices. In order to provide a basis of evaluation, three versions of the same prototype were developed in order to test different types of user inputs in regards to the easiest and comfortable one in regards of user experience. Moreover, based on the responses of test subjects regarding the most positive perceived type of user interaction, a full prototype was developed that imitates the real functionality of an inflight map application. During the process, a user-centered design approach was practiced in each iteration of the prototype based on a user centered design including user performance tests and interviews. Furthermore, an iterative process was adopted in order to further improve each iteration of the prototype.

Results of the final iteration of the prototype were positive in a usability point of view with minor improvement suggestions. Improvements regarding visual feedback and touch sensitivity were the more common suggestions in the earlier stages of the prototype. Drawing conclusions from user tests performed in earlier prototypes gave valuable information in order to iteratively produce new version which resulted in an improved user experience. The last iteration of the prototype had some suggestions of improvements which were not fully implemented and were reserved for future implementations. Lastly, the results of the user experience in the final iteration of the prototype presented a positive response regarding the user experience in an augmented reality based map application.

Keywords: In-Flight-Entertainment, Map Application, Mobile Augmented Reality, User-Centered Design, Unity3D

Sammanfattning

Inflight Entertainment (IFE) är det system passagerare kan interagera med vid långflygningar. Detta kan vara att se på film, spela spel och interagera med en kartapplikation. Förbättring av användarupplevelsen inom IFE är en process i konstant utveckling. Många av dagens flygbolag är i ett aktivt sökande efter nya teknologier som potentiellt kan stärka användarupplevelsen av dagens inflight entertainment.

Detta examensarbete har undersökt nya metoder för att förbättra användarinteraktionen inom inflight kartapplikationer som ger information om den aktuella flygrutten. Fokus har lagts på att undersöka lämpligheten av mobil augmented reality på passagerares egna devices. Som grund för utvärdering har tre iterationer av samma prototyp utvecklats för att testa olika typer av användar-input och studera de mest lämpliga av dessa. Baserat på svaren från testpersoner angående den bäst uppfattade användarinteraktionen producerades en slutlig prototyp som imiterar en verklig inflight kartapplikation. Varje iteration av prototypen baserades på en användarcenterad design innehållande användartester och intervjuer.

Resultaten av den slutgiltiga prototypen gavs positiv feedback utifrån användartester med enstaka förbättringsförslag. Tydligare visuell feedback och mindre tryckkänslig implementation i pekskärmen var de mer vanliga förbättringsförslagen i prototypens tidigaste stadier. Sammanställda resultat av användartester under prototypes tidigare faser gav god grund för att iterativt producera nya versioner vilket resulterade i en förbättrad användarupplevelser enligt användartesterna. Prototypens sista version resulterade i vissa förbättringsförslag enligt användartesterna vilket ej hann implementeras och fick agera som grund för framtida implementering. Resultaten av den sista iterationen av prototypen gav positiva användarupplevelser om hur passagerare kommer att uppfatta en augmented reality baserad kartapplikation.

Nyckelord: In-Flight-Entertainment, Kartapplikation, Mobil Augmented Reality, Användarcentrerad Design, Unity3D

Acknowledgments

Contents

1. Introduction

This chapter includes the background, purpose and goals and additional information regarding the history of map applications. In addition, a brief introduction of Tactel AB is included where the thesis work were carried out.

1.1 Background

The number of flights carried out in 2018 is estimated at 38.1 million [1]. This number is thought to dramatically increase in the future [2]. Flights equipped with in-flight entertainment (IFE) systems offer passengers ways of passing the flight time with entertainment such as movies and music. It is suggested that in-flight entertainment reduces the stress afflicted on passengers [3]. In addition, passengers in some airlines have the opportunity to interact with information about the current flight. This includes current location, estimated time of arrival, altitude, speed, etc. which in later context is called "map application". The design of a map application is crucial to mediate flight information to the passengers in an understandable manner. Furthermore, the interaction of the map application is important in order for the passenger to experience the intended visual understanding of the flight. Current interaction implementations of IFE mainly consists of remote control or touchscreen inputs done by the user which could be unsuitable when interacting with an map application. For instance, a remote control with a large number of buttons can be confusing when trying to operate a map application, especially for new passengers with no previous experience.

Many airlines seldom update their map applications which results in outdated versions offered to the passengers during the flight. Consequences may be unresponsive systems which further impacts the user experience negatively. Passengers mobile devices (smartphones, tablets) have strong computational power which is getting better for each year [4]. Making use of this computational power could potentially revolutionize the IFE map-industry which in return could benefit airlines looking for reduced expenditures. The smartphone has during the recent decade made a big impact on everyday life and becomes more and more a centralized unit for handling information. This would propose a future where users own devices would be responsible for showing information, including map information during flight.

1.2 Tactel AB

This thesis was done in cooperation with Tactel AB mainly at their office in Stockholm.
Tactel AB is a Swedish IT-company with approximately 92 employees [5]. It's a subsidiary company of Panasonic Avionics where they have developed solutions to Singapore and Etihad Airlines regarding their in-flight entertainment system. The thesis was suggested by them which focuses on the passenger interaction with their map application which is used in flights. Giving the passenger the

ability to further interact in more detail with the map application with a user-centered approach was in the interest of Tactel AB.

Tactel AB in cooperation with Etihad Airways and Panasonic have developed and designed a way of buying inflight WiFi onboard. The design of the WiFi portal is based on a pre-study focused on the purchase flow for purchases of internet connection on board, offering Etihad Airways one of the first custom portals for purchase of internet services [5].

1.3 Purpose and Goals

The purpose of this thesis was to provide an improved prototype solution regarding user interaction of map applications within IFE. The focus was on studying the user experience in mobile augmented reality settings when interacting with the map application running on the passengers own devices. Investigating the approach in which the map application is migrated to the personal devices of passengers were submitted in the thesis. In addition, studying the overall negative user experiences of the IFE map applications of today did further point to improvements which was to be taken into consideration when designing the prototype. The work done in the thesis explored an alternative approach for future implementations of IFE map applications and identified results that may affect user experience. Based on the results of the suitability of augmented reality applied on map applications, the thesis could provide insight and knowledge for future development of map applications. In other words, the result of this thesis could potentially provide valuable information for future iterations of map applications.

The prototype was based on interaction design principles where a user-centered approach was taken into consideration.

The following were the three main goals with the thesis:

- Studying the suitability of an augmented reality based map applications running on personal devices.
- Producing a prototype by iterative development based on usability tests and feedback from test subjects.
- Evaluate the benefits of using the passengers own devices compared to the hardware offered by airlines.

1.4 Brief Introduction of Inflight Entertainment (IFE) Map Applications

An IFE map application is a real-time flight information video channel broadcasted to personal televisions. In addition to displaying a map that illustrates the position and direction of the plane, the system gives the altitude, airspeed, outside air temperature, distance to the destination, distance from

the origination point, and local time. Real-time data from the aircraft's flight computer is the basis of the map application information [6].

"Airshow" was introduced in 1982 as the first map application designed for passengers. The application was invented by Airshow Inc which later become part of Rockwell Collins. Early adoptions of the map application system were made by KLM and Swissair [7]. Latest versions of map applications are offered by AdoniOne IFE, ICARUS Moving Map Systems, Airshow 4200 by Rockwell Collins, JetMap HD by HoneyWell Aerospace and Arc by Panasonic Avionics [7][8].

Arc has been designed and developed by Tactel AB and offers many new features including the industry's first personalized maps capability, new map as a Service (MaaS) technology and a wide range of map styles [8].
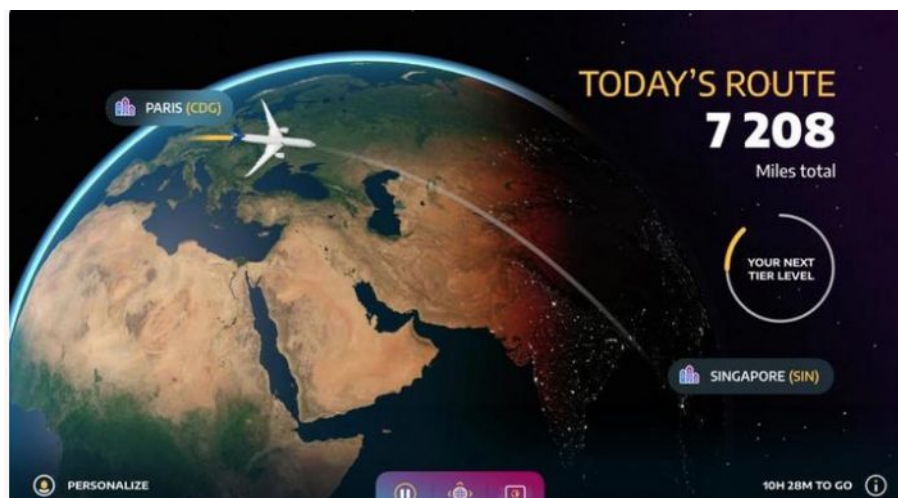
Figure 1. Panasonic Arc Inflight Map Platform.

1.5 Structure of the Thesis

The structure of the thesis work was as follows:
- ***Theory and Technology***: Theory regarding design principles when designing a geographical information system, touchscreen and remote control interfaces. In addition, an introduction of Unity3D and applications of augmented reality were provided.
- ***Methodology***: Covers the methods used in this thesis. This concludes the investigation phase, design phase and development phase and their corresponding contents. Moreover, a explanation of the iterative design process was provided.
- ***Results***: Presents the results found during the process. Results of the produced prototype iterations was provided with their corresponding user performance and experience tests was provided.
- ***Discussion***: Includes discussions of the found results. Suggestions of improvements of the produced prototype are discussed.
- ***Conclusion***: Presents the conclusion of the thesis and states whether the thesis have successfully achieved the goals declared.

2. Theory & Technology

This chapter describes the theory and overall design factors used when designing IFE map applications. Design factors of current forms of user inputs in IFE map applications are submitted.

2.1 User-Centered Design

In this thesis, a user-centered approach was to be used in the development. The foundation of User-centered design was formed in 1985 by Gould and Lewis which specified three principles they believed would lead to a useful and easy to use computer system [9].

1. ***Early focus on users and tasks.*** Understanding who the users would be by directly studying their cognitive, behavioral, anthropomorphic and attitudinal characteristics. This requires observing users doing their normal tasks, studying the nature of those tasks and then involving users in the design process.
2. ***Empirical measurement.*** The reactions and performance of intended users to printed scenarios, manuals, etc. is observed and measured. Later on, users interact with simulations and prototypes and their performance and reactions are observed, recorded and analyzed.
3. ***Iterative design.*** When problems are found in user testing, they are fixed and then more tests and observations are carried out to see the effects of the fixes. This means that design and development are iterative, with cycles of design, test, measure, and redesign being repeated as often as necessary.

2.2 Visualizing Geospatial Data

When designing map applications on IFE, one must consider the visualization of the geographical environment. How would the passengers cognitive ability to grasp information regarding the current latitude, longitude, and altitude? The word geospatial is used to indicate that data that has a geographic component to it. This means that the record in a dataset has locational information tied to hems such as geographic data in the form of coordinates, address, city or ZIP code [10].

In the context of IFE map applications, one must consider the intuitive design of the maps used. The following section presents different factors in order to visualize geospatial data in a proper manner.

2.2.1 Layers

Adding multiple layers showing different types of information is essential when visualizing geospatial data [11]. For a demonstration of this concept, visualization of wind turbines in the San Francisco Bay area are provided, see figure 2. The wind turbines are clustered in two locations.
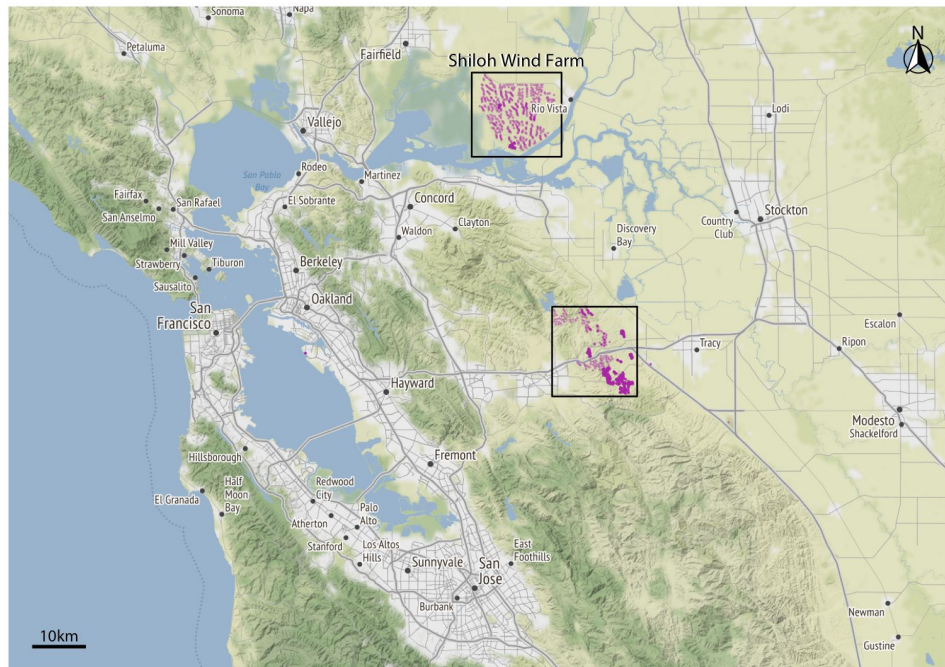

Figure 2. Wind turbines in the San Francisco Area. Squares indicate two different wind farms.

The figure above includes four separate layers. At the bottom, there's the terrain layer, which shows hills, valleys, and water. Next, the layer shows the road network. "On top of the road layer, there's a layer indicating the location of individual wind turbines. Finally, the top layer adds the locations and names of the names of cities. When designing maps, one might want to remove or add some of these layers in order to show the essential information in the current context. In the context of IFE map applications, infrastructure such as roads might be excessive however city labels might be of interest. Filtering out layers of information can be found in applications such as Google Earth where users can interactively choose which layer is shown (eg. satellite without country borders or a basic map with borders drawn). Regardless of which level of detail is shown, it is generally recommended to implement scale interaction and a compass. The scale would help the user understand the size of the spatial features and the compass clarifies the map's orientation. In addition, the scale affected on the map would have a direct correlation on the geospatial information shown. For instance, a zoomed in view would not necessarily have the same geospatial information as a zoomed out view, some important aspects when designing an IFE map application. Figure 3 shows different layers that figure 2 consists of; terrain, roads, wind turbines, city labels, and scale bars.
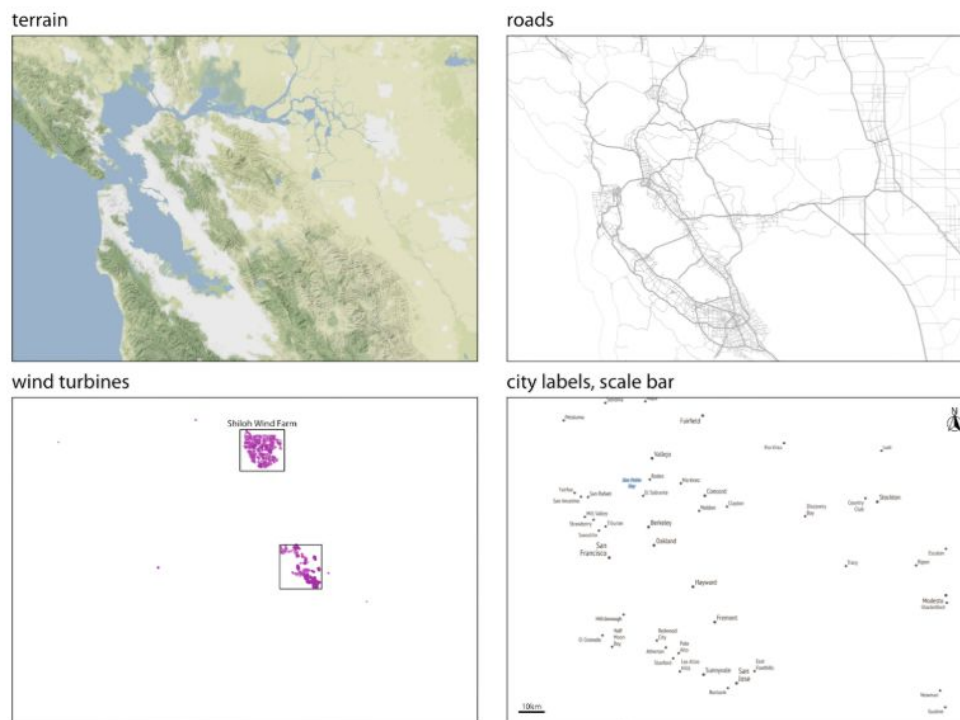
Figure 3. Different layers of geospatial data:
terrain, roads, wind turbines, city labels, and scale bar.

2.3 Effectiveness of 2D and 3D Map Visualization

The standard presentation of geospatial data is either a 2D or 3D visualization. The difference between the two dimensions would greatly affect how the end user would interact with the IFE map application. The following subsections discusses the effectiveness of 2D and 3D map visualizations.

2.3.1 Definition of 2D and 3D Maps

Before one could evaluate the effectiveness of 2D and 3D maps, their respective definitions must be given. 2D maps are defined as maps that depict the surface of Earth from a theoretical vantage point of directly overhead, in an orthogonal projection [12]. Two-dimensions maps have a relatively equal scale in the x and y dimensions. Used in many applications, the vast majority of maps available today are of the 2D variety.

What distinguishes 3D maps to 2D maps is a depiction of terrain in three dimensions and contain perspective that diminishes the scale of background areas. A definition by Häberling (2005) states that 3D maps as a "computer-generated perspective view of three-dimensional geo-data model with

cartographic content [12]. The following figures show a 2D respective 3D visualization of geo-data found in two different implementations of IFE map applications.
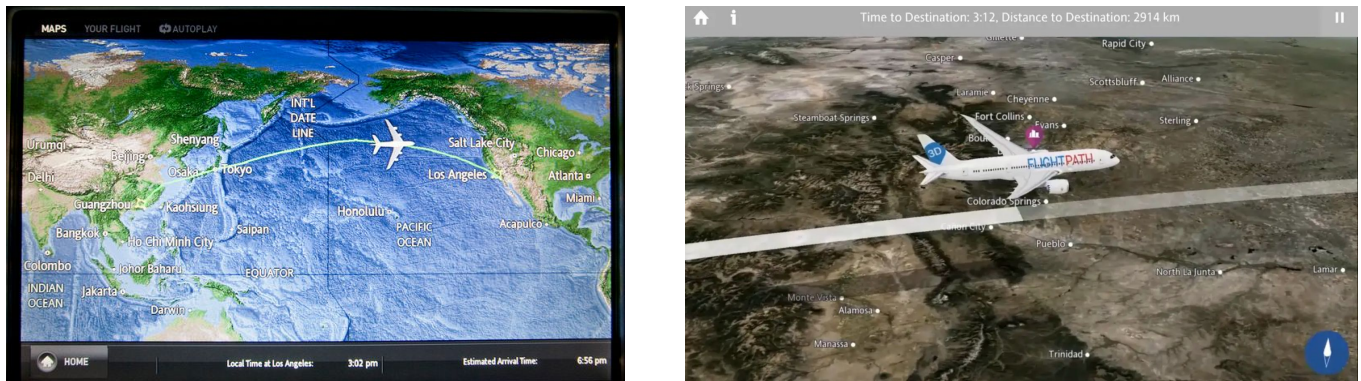

Figure 4. The 2D map (left) and 3D environments (right) of the different in-flight map applications.

2.3.2 Effectiveness of 2D and 3D Maps

Offering passengers an intuitive IFE map application, one must consider the effectiveness of 2D and 3D map visualization. Implementation of either 2D or 3D map would affect the overall user experience and would have a differentiating effect. The ICA Mountain Cartography Workshop conducted an empirical study on the effectiveness of 2D and 3D maps of trailhead maps. Differences in communication efficiency between 2D and 3D maps were the goal of the study. In addition, which type of map attracted the attention of more people and motivated them to go hiking, and the type of map preferred by park visitors was an objective. The study had 185 test subjects which were interviewed regarding background information, trailhead map interaction, cartographic communication, and orientation and direct preferences. Study findings showed that 3D maps enabled hikers to more accurately identify their position on the landscape compared to 2D maps, especially for older people (over 60 years of ages) and women [12].

In the context of attractiveness, 3D maps had more readers and on average was read for a few seconds more than 2D maps. Furthermore, respondents generally agreed that 3D maps depicted reality better. Regarding cartographic communication, readers of 3D maps had a better understanding of distances, topographic, and environment.

However, the findings were not necessarily valid internationally due to the results differences in map preference between native English speakers and those who are not. This suggests that a similar user study conducted elsewhere in the world would yield different results.

In the context of IFE map applications, attractiveness, in order to get the attention of the user is of major importance. Likewise, accurately identifying the position during flight is an essential feature, both in which 3D maps showed to be more suitable for. Moreover, increasing the dimension increases the amount of data attributes that can be displayed. This means that the representation of the real world becomes more accurate. However, drawback includes scalability, occlusion, and clutter [13].

2.4 User Interaction in Inflight Entertainment Systems (IFE)

A number of different types of user interaction are available in IFE of today. However, each type of user interaction has its benefits and drawbacks when used in a map application context. In order to create an intuitive map application, appropriate controllers of interaction must be used. The following section describes the current user inputs used in IFE systems of today.

2.4.1 IFE Remote Control Design Factors

One of most common navigation controller used for with IFE is built-in remotes. Different airlines offer different design of the remotes. Figure 5 shows an example of an IFE remote. However, every remote follows the same design pattern by offering the user navigation arrows and simple navigation buttons [14]. Similar to a tv remote control, many users have previous experience with the layout and feel comfortable with the form of the current form of interaction.

Figure 5. IFE remote control.

In "The design of everyday things", Don Norman mentions that natural mappings of remote controls can vary with the culture [15].

Norman brings up an example from when he held a lecture in Asia where he was given a remote control with two buttons for advancing through the illustrations in his talk. The two buttons on the remote control were one above the other. When Norman pressed the up button, the illustrations went backward instead of forward. He later asked the audience which button led to the next illustration in the presentation. To Norman's surprise, the audience was split in their response. This disagreement on which button that leads to the next illustration was noticeable to his audiences around the world. Norman later realized that this was a point-of-view nature. The top button does cause something to move forward, but what is moving? Some people thought that the person would move through the images, other people thought the images would move.

What Norman indicates is the issue of having fixed interactions in remote controls that could be interpreted for different actions [15]. In the aviation industry, this is an important aspect to consider where many different cultures interact with the same type of control. Unifying the design is crucial in order to mediate an intuitive layout.

In order to provide a logical and easily understood layout of a remote control, some key design factors are important to keep in mind. Buttons of a remote control should be logically positioned and grouped according to their functions. Providing a logical and easily understood layout is of major priority when designing an IFE remote control. Following are some of the most important guidelines in order to design an intuitive remote control [16]:

- Group related buttons together. This includes buttons for eg. volume up and down and arrow keys for navigation.
- The positioning of buttons should be consistent with functions, e.g. position the left-navigation arrow on the left and the right-navigation arrow on the right of each other.
- Include spaces between groups of buttons that relate to the same function greater than the spaces within the groups.

Regarding the vast majority that would interact with an IFE remote control, it is important to reduce the complexity of the remote. For instance, minimizing the number of buttons, still covering the necessary functions is a good design choice. Another approach to minimize complexity is to assign quick access buttons mapped to the most common functions. This allows a low learning curve where the buttons to the more commonly used functions are grouped together in a row, easily accessed by the user.

Regarding coloring of buttons, care should be taken into consideration due to the risk of confusion. Risks of confusion include standard color buttons that are referred to instructions of within programs. Red color coded buttons usually referred to as "shut down" or "record". However, in figure 6, the red button refers to fast forwards when watching a movie. It is important to consider previous experiences of users that draw conclusions of previously learned button color coding.

Figure 6. Color coded IFE remote control.

In addition, helping users recover from errors is an important aspect to consider. This can often be prevented by providing a dedicated "Back" button that takes the user to the menu, screen or function they have just left, allowing users to undo some types of mistakes.

As mentioned previously, due to the vast variety of passengers, it is important to ensure that the IFE remote control can be used with a low physical effort. Passengers may have reduced dexterity or strength in their hands. A natural consequence of this includes difficulty in holding the IFE remote in the correct position and press buttons without accidentally pressing other buttons at the same time. Aiding passengers with these physical limitations can be done in a number of ways. Introducing large buttons with a wide space, where impactful buttons (eg. on/off-button) is isolated is a recommended precaution [17]. To facilitate the pressing of the buttons, making them easier to push down, a concave shape is recommended.

Regarding the overall design of the remote control, it should be easy to grip. Applying an easy-grip textured surface that would not slip or turn in the hand is of interest [17]. In addition, it should be stable enough when placed on a flat surface to be operated with one finger. This would improve the user experience for people with limited motor skills. Avoiding accidental operations by implementing a button layout that prevents buttons being activated when they are unintentionally touched is an important design aspect.

2.4.2 Touchscreen Design Factors

In 2018, the estimated amount of touch-enabled smartphones was 2.53 billion [18]. This number indicates that a large part of the world's population is familiar with touch screen technology. Moreover, touchscreen technology has many advantages. Easy operations are made possible for inexperienced and disabled users. Less training is also required than other input devices, such as remote controls. Physical buttons can be replaced by on-screen virtual buttons, thus minimizing the physical size of the device. In addition, touchscreen interfaces can easily be adjusted in terms of button shape, size, and style [14].

However, significant limitations in touchscreen technology such as reduced precision, finger occlusion and the lack of clear feedback on the state of interaction are important aspects to consider. Effective user interaction could deteriorate caused by these limitations. Prevention of the limitations includes touchscreen design factors that may affect the use of the technology and provide usable touchscreen interfaces.
Design factors regarding button design can have a large impact on user performance and perceptions. Recent studies have suggested that the effects of button size and spacing differed across personal and environmental conditions [19].

When designing touchscreen interfaces it is essential to consider how the user would receive feedback whether the user's input has been recognized. Feedback reduces efforts and minimizes confusion, which might help avoid user's negative perception of usability towards the touchscreen interface. Visual, auditory and tactile feedback are types of feedback among which visual feedback is the most widely used. In moving and noisy environments, auditory and tactile feedback is inferior to visual feedback. Visual feedback is less sensitive to the surrounding environment and has in several studies been confirmed to improve the effectiveness of the touchscreen interface [19].

Designing touch interfaces requires clear hints and directions on what the user can do when interacting with the system. In order to mediate the correct type of interaction, the term affordance

could be applied. Don Norman describes affordance as what an object can do based on user interaction [15]. It refers to the relationship between a physical object and a person. An affordance is a relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used. Taking a chair as an example, the chair affords ("is for") sitting. However, an affordance is jointly determined by the qualities of the object and the abilities of the agent that is interacting. This means that depending on the attributes of the agent, the level of affordance varies.

The need to clarify an affordance can sometimes be necessary. This is done by signifiers which illustrate or describes what an object can do [15]. Good communication of the purpose of an object is important factors where signifiers work as a helping hand. Signifiers can be blatantly obvious or very subtle. Norman defines signifiers as any mark or sound, any perceivable indicator that communicates appropriate behavior to a person. An example of a signifier is the text "push/pull" on doors in order to communicate the correct way of interaction. Figure 7 below shows an implementation of signifiers to communicate clues of how to interact with the interface.
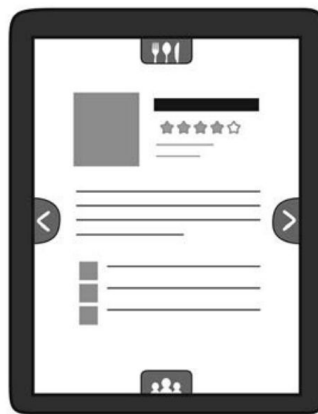
Figure 7. Signifiers on a Touch Screen.
Arrows and icons act as signifiers.

An understandable and well-behaved interface requires a great level of consistency. Sequences for actions in similar situations are crucial to have consistency; menus and help screens should all have consistent colors, layout, and font to mediate an easily understandable way of interaction. However, exceptions such as using the sensors of a device should be comprehensible and limited in number.

Consistency flaws in web-mapping includes pan/zoom/identify buttons. Zooming functionality can sometimes have inconsistent operations, such that zoom might require drawing a window on the screen while zooming out might require a single click. In order to remain consistent, it is important to follow the same operations. A detailed user requirement document would prevent inconsistency regarding user interaction [20].

2.5 Unity 3D

Unity 3D is a cross-platform real-time engine developed by Unity Technologies [21]. The engine gives the user the ability to create interactive experiences in 3D and offers primary scripting in C#. One of the major uses of Unity 3D is the vast support for different platforms, both in terms of development and execution.

The major reason for the development of the prototype in Unity 3D is the possibilities of exploration regarding gyroscopic sensors in mobile devices. The emerging technology of virtual and augmented reality is important to take into consideration when prototyping new ways of interacting with the map application of IFE. Unity 3D has support for many types of user inputs. This in return enables more user tests and experiment with different forms of user inputs (user interactions). Benefits such as direct playback when testing applications is valuable for agile testing. In addition, Unity 3D provides a wide range of 3D-object manipulation techniques that is suitable when designing an IFE map application.

Due to Unity 3D's incorporation of C# scripts affecting the behavior on objects used, this facilitated endless possibilities when prototyping the application. Using C# scripting made it possible to fetch gyro information of the connected device, allowing for the simulation of augmented reality. In addition, the canvas component in each scene allowed for the implementation of a menu like interfaces, including buttons triggering animations and scene transitions. A supplement application to Unity 3D is Unity Remote 5. Unity Remote 5 made it possible for continuous testing on devices, allowing execution of Unity 3D-applications on mobile devices, eg. Android and iOS [22]. Without the powerful tool of Unity Remote 5, the application would have to build each time which would yield much wasted time waiting in order to run.

In order to support the theory regarding touchscreen design factors (see section 2.4.2) including principles of visual feedback, Unity 3D offered many tools for making this possible. Regarding screen size, many different screen ratios made it possible for the execution of bigger devices, such as tablets and higher resolution devices. As a natural effect of the eligibility of screen ratios, the prototype is executable on a variety of devices. Moreover, due to the flexibility of the C# scripting used for fetching gyro sensor data, each mobile device connected would have its gyro sensor data as parameters allowing for navigation in the prototype.
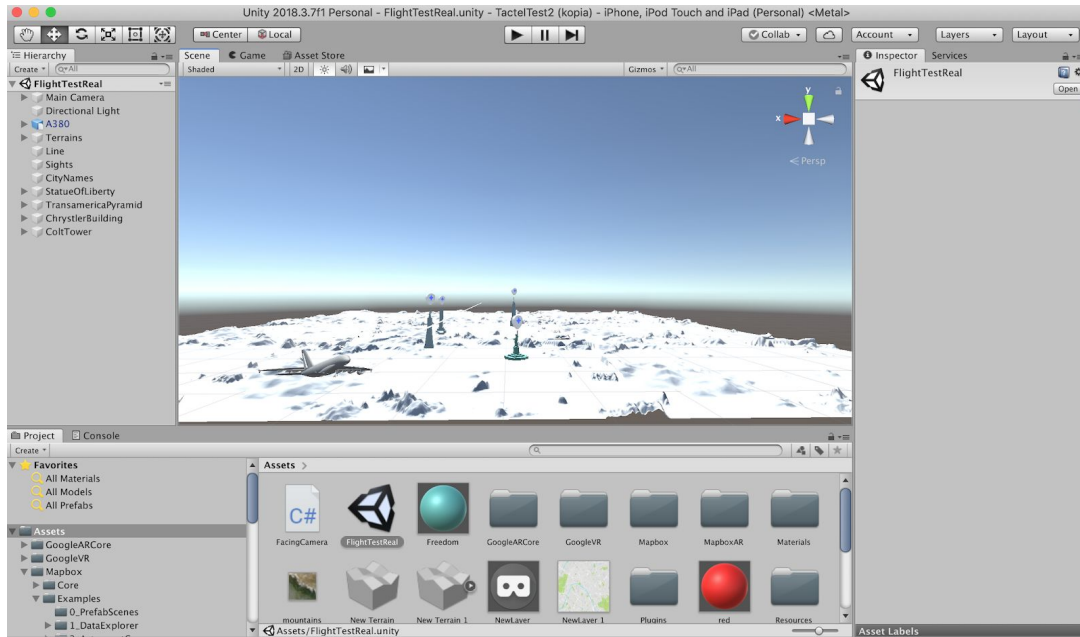
Figure 8. Unity 3D project.

2.6 Applications of Augmented Reality

Augmented reality is a technology that incorporates digital or virtual elements in a real-world environment. By overlaying constructive sensory information, augmented reality allows for a seamlessly interwoven and immersive perception of the real environment [23]. Applications based on augmented reality brings components of the digital world into a person's perception of the real world perceived as natural parts of the environment.

As of today, application areas of augmented reality include archaeology, architecture, commerce, and education. However, the suitability of augmented reality within IFE has yet to be further be investigated. Considering the geographical information when inflight, augmented reality has a great potential in making the IFE more intractable and intuitive to use. Application areas such as tourism and sightseeing have big potential by augmented reality, where users get access to real-time informational displays regarding locations, its features, and comments.

2.6.1 The Potential for Mobile Augmented Reality

Augmented Reality can be found in a many different types of applications. During recent years, applications such as Pokémon Go have shown the utilization of augmented reality on modern smartphones [24]. Moreover, the development of sensor and communication technologies allows for context-aware mobile-devices where measurements of the user's location is made and provides location-based information with physical objects in the surroundings [25].

The rich mobile environment of smartphones and tablets in combination with mobile augmented reality expands traditional AR services use cases and scenarios. Benefits of context awareness in mobile augmented reality further includes context-related information that could be very relevant, useful or entertaining in the very moment and location. A great potential of mobile augmented reality

is IFE map applications, where the location-based information could be of great interest of the passengers. The long flight includes different countries, their respective cities, and further sightseeing. Offering passengers an augmented reality setting in combination with a user-friendly interface, a potential of creating a pleasurable and rich flight-experience emerges.

2.6.2 Magic Window - Simulation of Augmented Reality

"Magic Window" is a technique that allows users to view 360° virtual reality content without a VR headset [26]. It simply renders a monoscopic view of a 3D scene that is updated based on the device's orientation sensor. The name "Magic Window" refers to creating a "window" that allows the user to interact with a 3D scene. This technique allows for testing of simulated augmented reality where the device's built-in orientation sensor matches the virtual camera's rotation in a 3D scene. In the context of an IFE map application, creating a geographical 3D map that represents the current flight route with a virtual camera that is rotated based on the device's built-in orientation sensor, a simulation of augmented reality is created.

3. Methodology

This chapter takes on the different methods used during the thesis. Major phases consisted of pre-study and prototyping. During the pre-study, a literature study, collection of quantitative data and a brainstorming session were held in order to lay the groundwork of the thesis. Results drawn from the pre-phase was later applied on development of the prototypes with the purpose of improvement. Finally, an iterative process was applied to each prototype with an evaluation after each iteration. The overall methodology can be seen in figure 9.
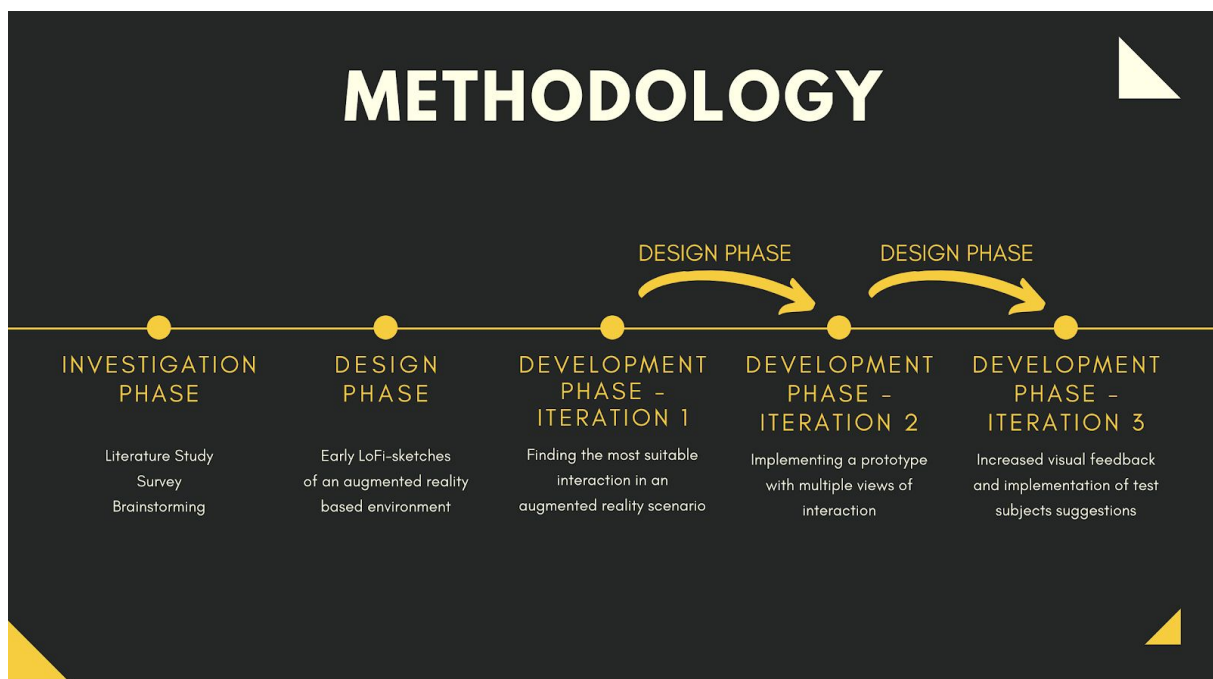
Figure 9. The overall methodology used in the thesis.

3.1 Investigation Phase

This section covers the methodology and tools used during the research phase. Researching material regarding visualization of geospatial data in combination with design factors of current IFE controls made for a strong basis at the start of the process. Moreover, an extensive survey was sent out to experienced passengers with the purpose of presenting indications of improvements in IFE map applications of today. Lastly, a brainstorming session was held which had the results from the questionnaire in mind.

3.1.1 Literature Study

In the initial stage of the thesis work, a comprehensive literature study was carried out. The literature study was mainly done online with some exception of course literature in physical copies. Some of the more valuable sources of information were derived from Research Gate offering a vast number of scientific articles [27].

During the research of design evaluations of map applications in IFE, not many studies on this specific topic had been done before. Research regarding user interaction in inflight entertainment map applications gets very limited due to its relatively unknown research area. Since map application in IFE primarily presents geospatial information (position, altitude), studies on interacting with geospatial technologies had a large focus. In addition, research on how current IFE user inputs could affect the usability was conducted.

To get a better understanding of the current user interactions with the IFE, a comprehensive study on the overall usability of the available forms of interactions were made. One of the major parts of the study was to evaluate the suitability of the different forms of interactions regarding map navigation. Since remote controls and touchscreens were two of the most commonly used forms of user inputs with map applications, was there any way to improve the design of the map application with new ways of user interaction? How could the current user inputs be utilized in order to benefit usability? The emerging technology of augmented reality and its applications was an immediate thought at the beginning of the literature study. It's been proven to have many areas of application in many sectors to further visualize information in a more intuitive fashion [23]. Applying this concept when visualizing geospatial information was an exciting and futuristic approach.

3.1.2 Survey - Overall User Experience of Map Applications Used Today

In order to get an understanding of the general perception of map applications used today, a quantitative data collection in the form of a survey had to be performed. Receiving opinions from experienced passengers on what could be improved in map applications of today were of great interest. Regarding target groups, the questionnaire was mainly published at two big public forums regarding flight travel: "Flygforum" and "Flygpostlådan" on Facebook. The two groups have 5 177 followers combined where the users are well experienced regarding inflight map navigation. The posting of the questionnaire sparked an interest, resulting in many opinions on how to improve the current design and functionality of maps applications.

Getting respondents thoughts on disaffection regarding IFE map applications and suggestions on further improvements was an additional ambition of the survey. Answer fields were therefore contained where respondents could freely express their thoughts. This was very valuable due to the vast number of experienced passengers that participated in the survey. Following are some of the questions that were used to receive a perception of the general user experience of map applications used within inflight entertainment systems:

- *Age?*
- *How often do you fly?*
- *Do you have previous experience with IFE-navigation?*
- *What kind of remote/user interaction did you use to interact with the IFE?*
- *Did you receive any information of value during the flight?*
- *Did you experience any dissatisfaction when interacting with the IFE map application?*
- *What's your suggestions of improvements regarding IFE map applications used today?*
- *Would you use the opportunity to use your own device as a complement to the IFE map applications of today?*
- *Would you be interested in engaging in interviews as a part of my thesis-work regarding user interaction of IFE map applications?*

The questionnaire used in for quantitative data collection with corresponding answers can be found in Appendix A.

Construction of the Survey regarding overall user experience of map applications of today

Regarding the questions used in the survey, the reasoning were as follows for each questions:

- "*Age*?": Asked in order to see the overall age distribution after all the questions had been answered. This would indicate if the answers of the survey were limited to specific age groups or not.
- "*How often do you fly?*": The results of this question would indicate if the user's asked were regular flyers or not. Based on the results, one could link the questions with the respondents respective flight experience.
- "*What kind of remote/user interaction did you use to interact with the IFE*": Asked in order to receive the most common way of user interaction. Based on this result, one would be able to see the type of user interaction that most passengers were used to. This can be linked chapter 2.4.2 and 2.4.3 regarding different types of user interaction within an interface. The received results would indicate whether the passengers had a pre-learned experience when interacting with an IFE map application.
- "*Did you receive any information of value during the flight*?": Asked in order to receive the most requested information that should be displayed within the IFE map application. The question was later taken in consideration when designing the iterations of the prototype.
- "*Did you experience any dissatisfaction when interacting with the IFE map application?*": The question was asked in order to get an indication of the inadequate features of IFE map applications of today. Focus on improving the most agreed on inadequate features was a priority.

- "*What's your suggestions of improvements regarding IFE map applications used today?*": Receiving suggestions of improvements from the respondents were a great resource of inspiration regarding design choices.
- "*Would you use the opportunity to use your own device as a complement to the IFE map applications of today?*": Asked in order to study the overall positive attitude of using passengers own devices. Based on the results, indications on whether the direction of having a mobile IFE map application running on passengers own devices was correct or not.
- "*Would you be interested in engaging in interviews as a part of my thesis-work regarding user interaction of IFE map applications?*": This question was added last in the survey and would make the arrangements of conducting interviews more effective rather than simply searching interview subjects single handed.

3.1.3 Brainstorming

Receiving results of the survey respondents stated in section 3.1.2 allowed for a big scope of design choices. Studying the most frequent points of dissatisfaction and suggestions of improvement unfolded different ideas of user interaction. These ideas were written down in a brainstorming document and presented in a mind-map and corresponding aspects of user interaction, see figure 10. With the purpose of finding new ways of user interactions, the brainstorming session was deeply affected by ideas on utilizing augmented reality within the IFE map applications. Indications of a positive attitude to using passengers own devices within IFE further suggested the utilization of augmented reality, see section "*4.1 Results - Survey*" .
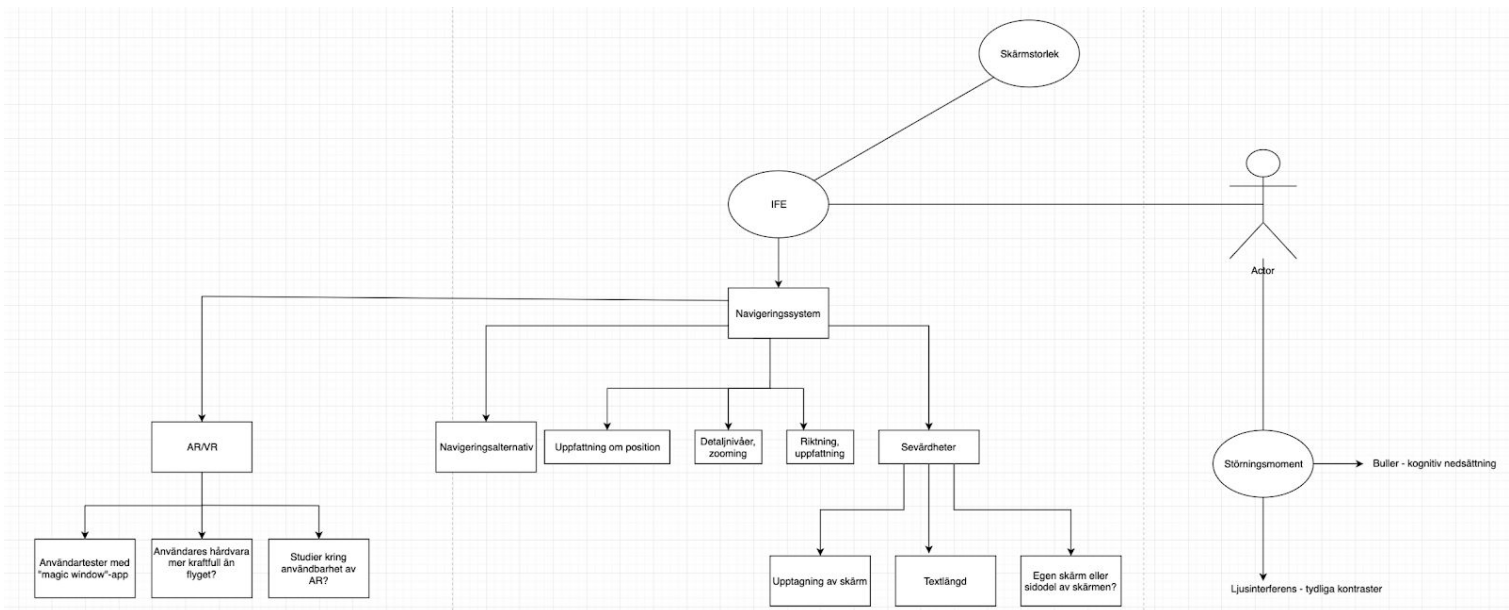

Figure 10. Mind map of aspects of user interaction with an IFE map application.

The choice of integrating suggestions for improvement within the questionnaire described in section 3.1.2 was to receive a large number of answers of flight-experienced respondents. This allowed for effective idea-gathering with a total number of 93 improvement suggestions. A traditional approach of brainstorming by eg. using post-it notes, would have been time-consuming and would've been hard to include a large number of participants .

Based on the survey respondents answers and mind map of aspects (seen in figure 10) some sketches of an augmented reality view within an virtual IFE map applications were made. Different ways of user interaction were added in the sketches in the forms of arrows. Moreover, design ideas of how the user would receive geographical information was integrated within the sketches.

3.2 Design Phase

During the design phase, an iterative process was early adopted. To get the most time efficient testing process, specific sections of the map application prototype were studied in different tests. The methodology used in this thesis followed an iterative design process where the early focus was held on developing iterations of the augmented reality prototype. The choice of starting development with a focus on simulating augmented reality and work from there was made in order to get the most time in evaluating the suitability of augmented reality in IFE map applications.

3.2.1 Iterative Design Process

Development of the different prototypes was based on an iterative design process where the cyclic process of prototyping, testing and improving the current product was applied. Adopting an iterative design process includes iterative testing which yields continuous improvement of the product at hand [28].
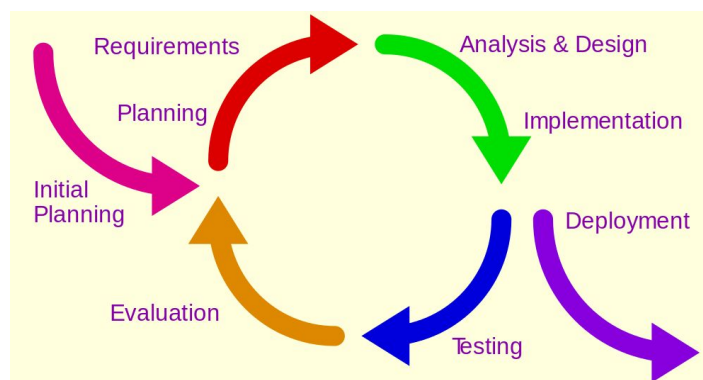
Figure 11. The iterative design process.

The iterative design process could be explained as follows. Identify a user need and generate ideas to meet that need. Next, develop a prototype based on the ideas and perform user tests. Take what you learned from the tests and amend the design. Following that, you create a new prototype and begin the process all over again until you are satisfied that you've reached the best possible product for release to the market. The process of iterative design is summarized in figure 11.

The development of the prototypes was divided into small increments, enabling potential end users to evaluate the product and to receive feedback during the whole prototyping process. Arguments for adopting an iterative design process are easy adaptations and changes in the course in response to the unknown or unexpected [29]. This in contrast to the waterfall model where specific design directions get locked once production is underway. Due to a user-centered and empirical study where improvements of prototypes were of interest, working agile was a natural way of progression.

Iterative Testing

In order to get an indication of improvement the final phase of each prototype ended with a test- and evaluation session. Each test was conducted with four test subjects with varying degrees of experience of IFE map applications. In every test, new sets of test subjects participated with a various degree of previous experience with IFE map applications. Tasks that test subjects had to perform were unified in both tests and can be found in the appendix. A unified test plan allowed for further study of the improvement of each iteration regarding both time it took to complete each task and the overall user experience. After each test session, the test subjects were asked to fill out a System Usability Scale (SUS) questionnaire containing 10 questions regarding usability [30] where each question was rated between 1-5, (1 = strongly disagree, 5 = strongly agree). The scale used was based on the "Likert scale" with the benefit of creating an average of questionnaire responses over the set of individual items (questions) [31]. To get a deeper understanding of the thought-process, each test subject was asked to think aloud when performing each task.

Furthermore, to get an indication of the more difficult tasks a set of four questions were added in the SUS questionnaire. This helped to get a concrete understanding of what specific tasks and their corresponding part in the prototype could be improved. The added qualitative questions were the following:

1. Did you need any more hints in order to understand how the prototype worked?
2. Which part was the hardest to understand?
3. How easy did you think it was to perform the tasks?
4. Did you think it was hard to find information regarding the flight?

3.2.2 Evaluation

The process of evaluation during the thesis work was based on qualitative and quantitative data collection. Due to a large number of responses from the questionnaire regarding the general user experience of IFE map applications of today, the quantitative data set made for a great source of indications of improvements. Additionally, the collection of quantitative data included average time data of users performing tasks during evaluation tests.

Qualitative data collection included interviews and answer fields in the questionnaire where users were asked to fill out in detail their opinions on specific matters regarding usability. Evaluation using System Usability Scale-questionnaire complemented interviews conducted to further improve the qualitative data. Results from the qualitative data resulted in mutual suggestions by users of improvements in IFE map applications. These mutual suggestions of improvements were later

converted into specific questions of evaluation in order to see if the prototype fulfilled the requirements specified by the quantitative data.

Two major approaches were held when performing evaluation regarding the tests of the prototypes. At the beginning of the prototype development, the evaluation was focused on different types of user input in an augmented reality environment. Studying and evaluating the user experience for each user input made it possible to filter out the least suitable user input and progress with the best. The most suitable user input would later be fully implemented in the next version of the prototype.

Next, the evaluation of the overall navigational aspect of the prototype was of interest. By using test tasks for the user to perform and using a System Usability Scale-questionnaire with expanded questions about the user experience, a measure of the current usability of the prototype could be estimated.

Based on the received results from the evaluation of the navigational aspect in the second iteration of the prototype, the quantitative and qualitative data was taken into consideration when designing the third iteration of the prototype.

3.3 Development Phase

The development phase was iteratively performed after each design phase. The main purpose with the development phase was to implement the design decisions made in the previous phase in order to further expand the prototype. In this phase, Unity3D was the main tool for development with Unity Remote 5 allowing for instant testing of the prototype. Figure 12 shows the setup used in the development phase.
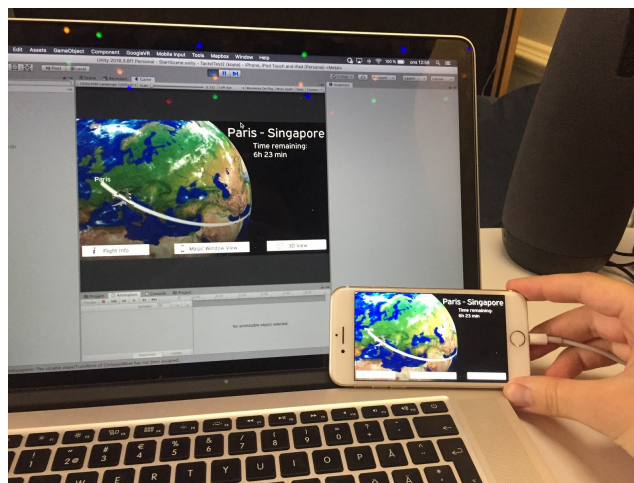
Figure 12. The setup used in the development phase. Unity 3D was running on the computer and Unity Remote 5 was running on the iPhone 7.

4. Results

The following section presents the results. The results was mainly the questionnaire, the first iteration of the prototype, the second iteration and the third iteration with their corresponding user test results.

4.1 Survey - Results

The results given by the survey gave a deep understanding of the user experience of the inflight entertainment systems of today. As a result of the engagement of the people answering the survey, 161 answers were registered. A large number of participants delivered great certainty of what the flaws and improvements were of inflight entertainment map applications.
The structure of the questionnaire can be found in the appendix. The results are presented below:
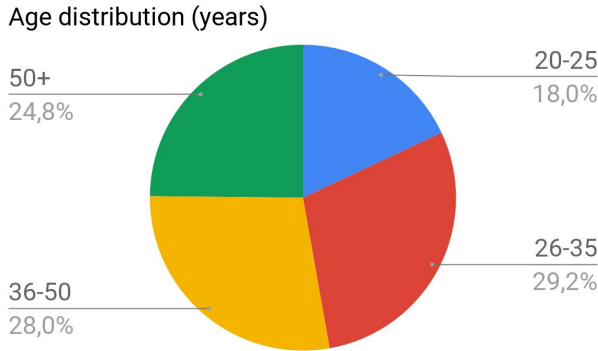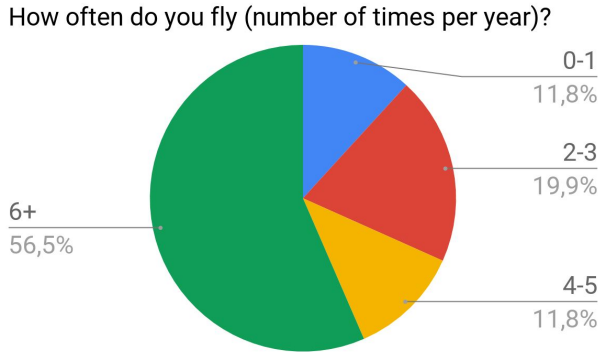

Figure 13. Age distribution.

Figure 14. "How often do you fly?"

Do you have previous experience of using IFE?
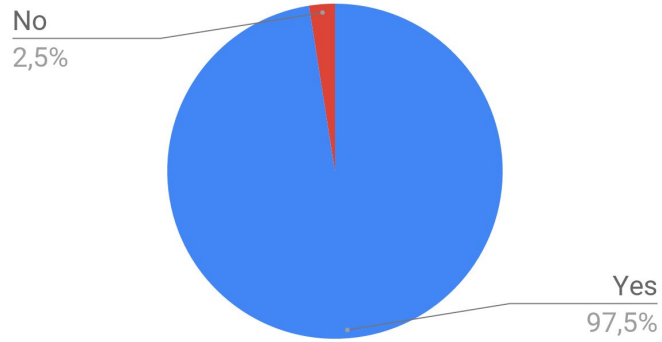
Figure 15. Respondents previous experience with IFE.

What type of control did you use for interaction with the IFE?
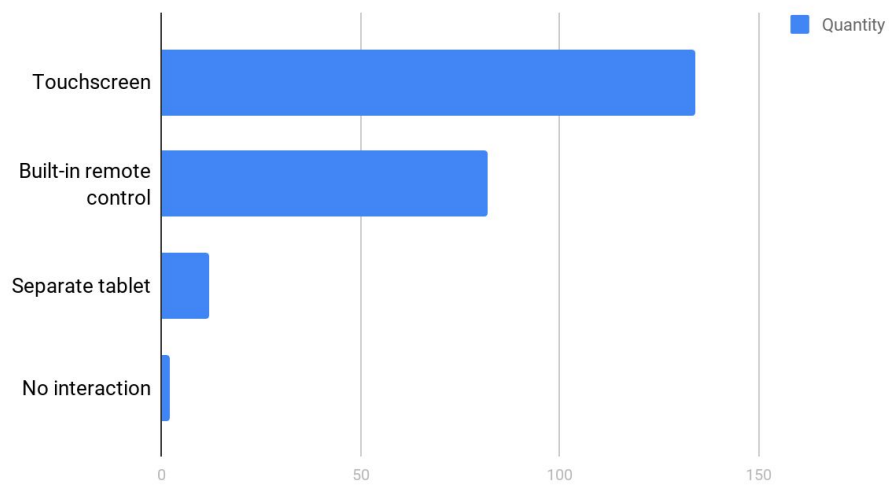
Figure 16. Different types of interaction used in IFE.

Did you receive any valuable information by the IFE during the flight?
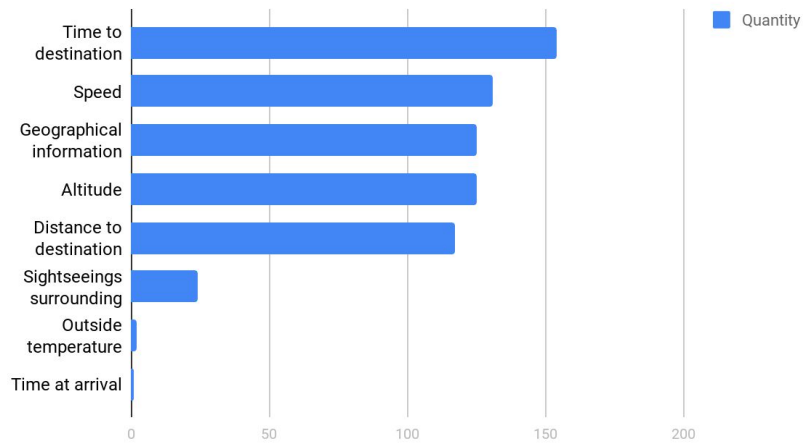
Figure 17. Most valuable information suggested by the respondents.

Would you like to use your own device as a complement to IFE map application?
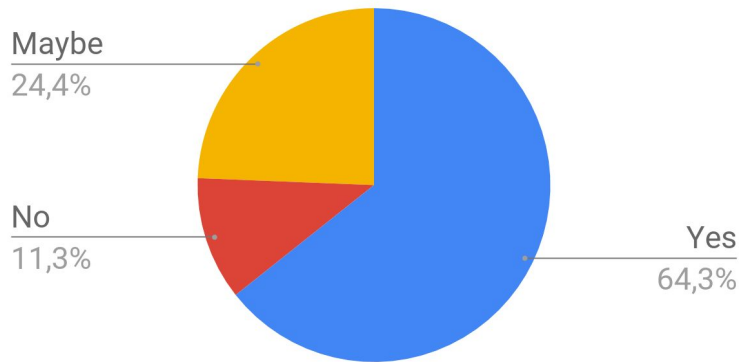
Figure 18. "Would you like to use your own device as a compliment to the IFE map application?"

In the latter part of the questionnaire, the subjects were asked to point out what the more dissatisfying features of their experience with IFE map applications. In addition, subjects were asked to find improvements with current map applications. The prioritized results are presented in the following two diagrams based on 78 respectively 93 number of answers.

Did you experience any dissatisfaction when interacting with the map application, if so, what?
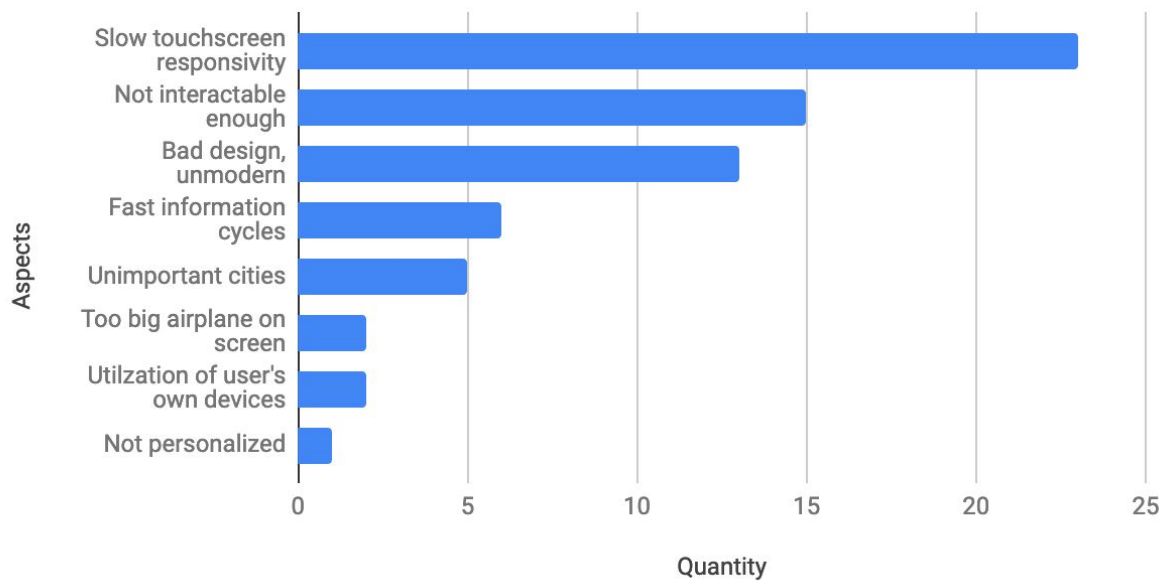
Figure 19. Most dissatisfying features of an IFE map application.

Suggestions for improvement
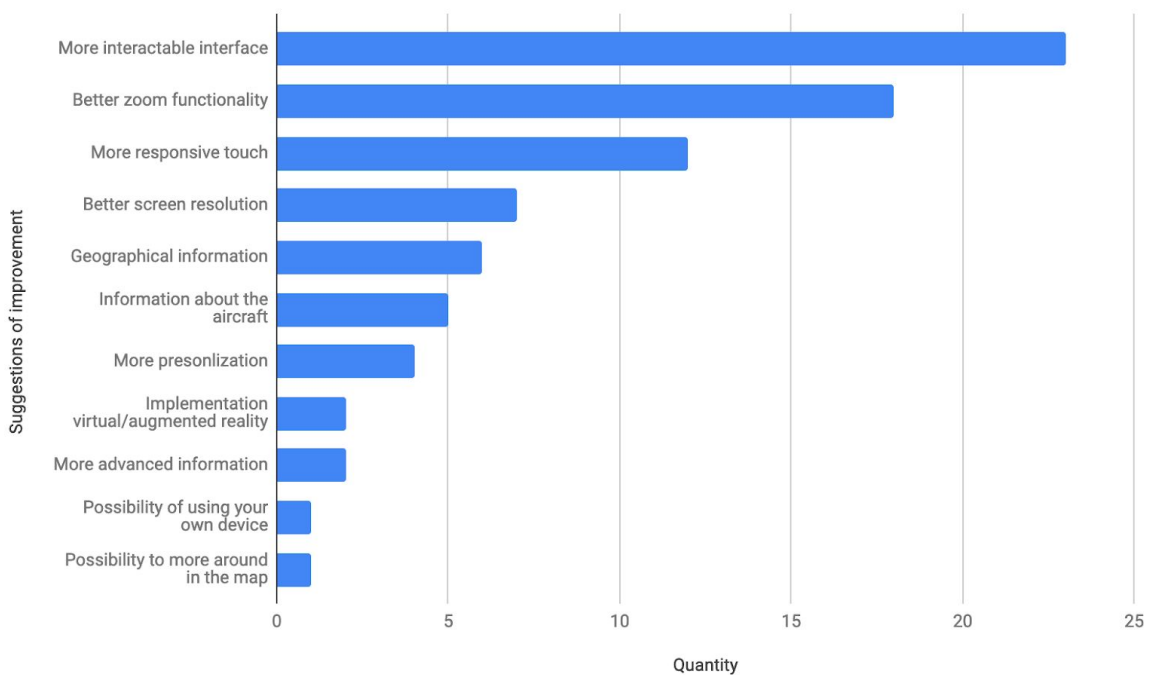
Figure 20. Suggestions for improvement.

As a result of a large number of respondents, valuable information of overall user experience would be taken into consideration when designing the prototypes.

4.2 Brainstorming

The results from the brainstorming session can be seen in figures 21 and 22. Sketches of an augmented reality based IFE map application was the first approach based on the positive feedback from the survey regarding improvements of current map applications within IFE. The sketches shown in figure 21 and 22 shows a virtual device running an augmented reality IFE map application.
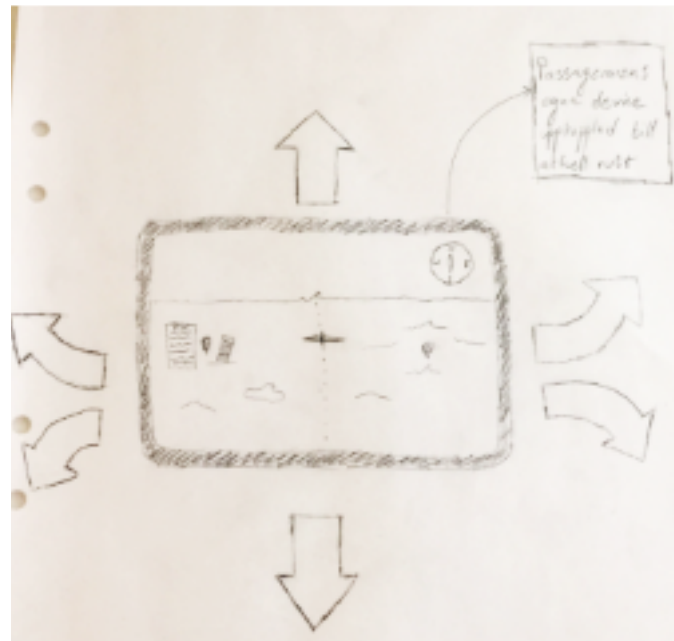
Figure 21. Early sketch of the user perspective from an augmented reality-based map application.
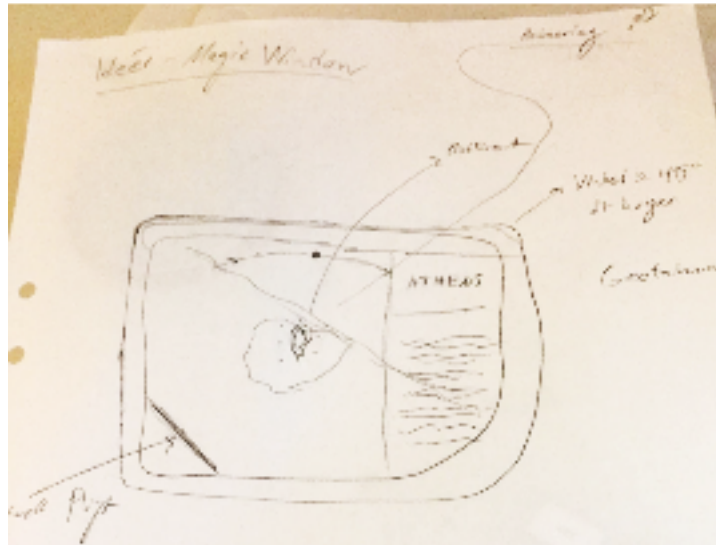
Figure 22. Early sketch of user perspective from the side perspective of an augmented reality-based map application.

The concept of the sketches presents a view where the user has the application running on their own smartphone or tablet. Figure 22 represents the view when the user has tilted their device and thus have received geographical information that corresponds with the position of the device. An information box about the selected point-of-interest on the right side appears on the right side of the screen.

4.3 Performance Evaluation of Augmented Reality

The first iteration of the prototype was the result of the brainstorming sessions, literature study, and survey regarding the overall opinion of IFE map applications of today. In this prototype, the user was introduced to a perspective behind an aircraft. The purpose of the first iteration of the prototype was to explore the suitability of augmented reality by using different sensors of the device and further evaluate the most suitable type of user input.

User interaction was done by rotating the virtual camera by using different sensors of the device for looking around, thus simulating augmented reality. This prototype was constructed in order to test three different types of user interactions with three different types of input: Bluetooth remote control, gyro sensor in device and touchscreen. At the center of the screen, a red marker is placed with the purpose of marking points of interests (eg. cities). The aircraft acted as an indication of the location in order to ease the sense of direction when looking around.

Placed on the terrain were cubes with pins above that changes color to blue when passengers focuses a red marker on them. The cubes represents Point-of-Interests and are placeholders for eg. cities in an augmented reality scenario. The positioning of the cubes is shown in figures 23 and 26.

The reasoning for positioning the cubes in this specific order was to test the agility and suitability of the different types of interaction implemented in this prototype. Cubes at the far right and left sections of the view are meant to challenge the user with harder angles and sort out methods that don't meet the level of accuracy required. Note that figure 23 has not rendered the texture, hence the white shade of the terrain. The first iteration was displayed on an iPhone 7 where the user would interact with the prototype by using different sensors of iPhone 7.
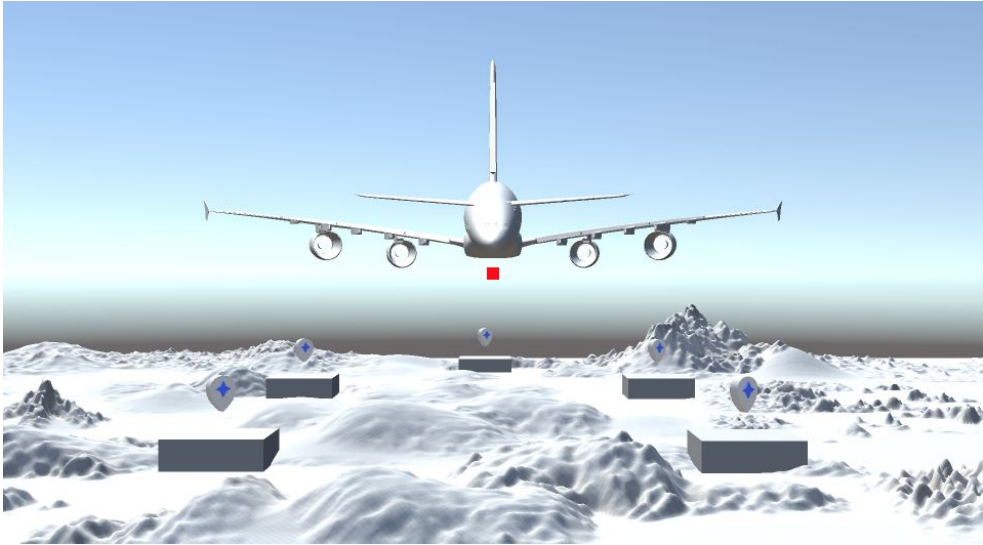
Figure 23. User perspective of the first iteration of the prototype.
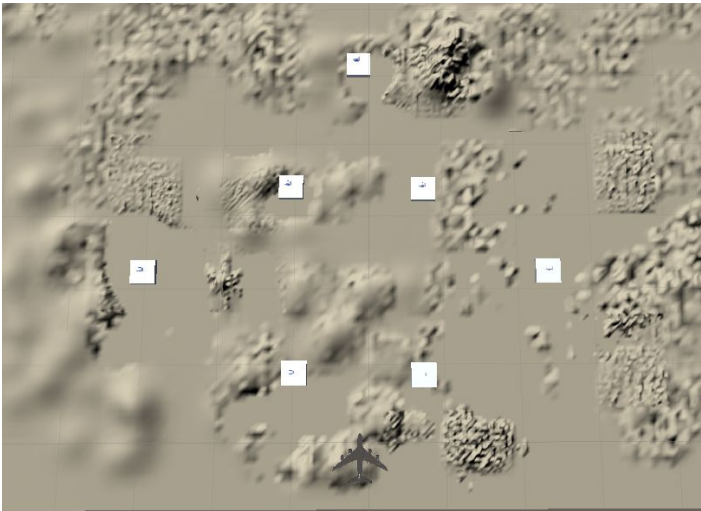
Figure 24. Cube positions in the first iteration of the prototype.
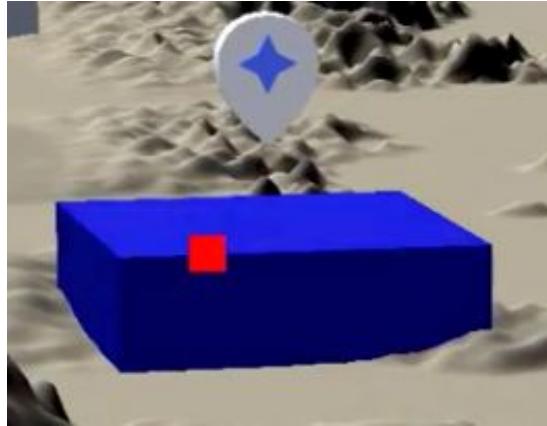
Figure 25. The cube turns blue when the marker is pointed at it.
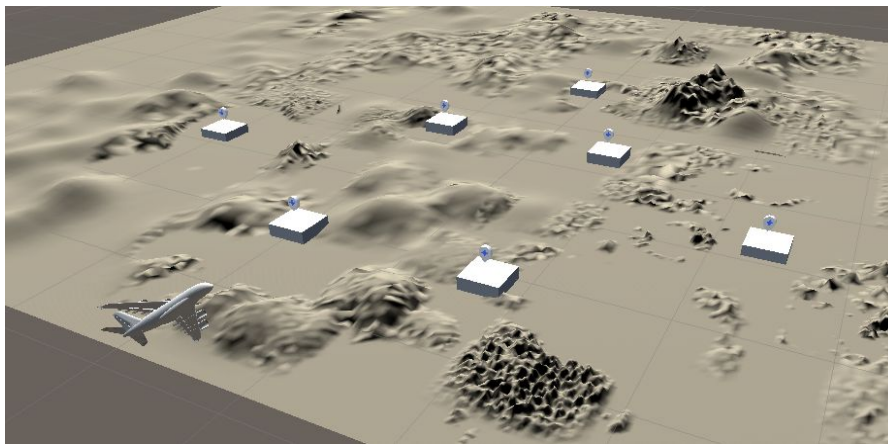
Figure 26. Side perspective of the first iteration of the prototype.

4.3.1 User Performance Testing

Implementation of appropriate user interaction is essential for good usability. In order to find the most suitable user interaction of the first iteration of the prototype, three different tests of user interactions were conducted: Bluetooth remote control, gyro sensors in device and touchscreen.

Each user interaction variant had two different types of tests. First, in test 1 the test subjects were asked to hold the marker for 2-3 seconds on each cube in order to test the sensation of control and accuracy. Later in test 2, the test subjects were asked to mark all 7 cubes as quickly as possible in order to study the fastest ways of interaction. After each test, the test subject was asked to fill out a questionnaire regarding the overall experience of using the different forms of interactions. The questionnaire used can be found in the appendix. The following subsections presents the results for each of the three ways of user interaction. Metrics of the evaluation was based on the "Likert Scale", where scores varies between 1 (strongly disagree) and 5 (strongly agree) [30].

Bluetooth Remote Control - Nintendo Joy-Con

Nintendo Joy-Con is the primary controller of the Nintendo Switch video game console [32]. They consist of two individual units, each containing an analog stick and an array of buttons. The control shares many characteristics with the remotes used in IFE systems of today. In this specific study, the right Joy-Con was used to represent an IFE system remote control, see figure 27. Rotating the camera was made by using the right stick with eight directions of navigation. Due to Unity 3D's support of Bluetooth inputs this test was made possible. The process of input conversion was to map each axis on the Joy-Con controller to each of the mouse x and y values.

Figure 27. Nintendo Joy-Con remote control.

Presented below are the results from the questionnaire regarding accuracy when Joy-Con was used. The questionnaire used in this test can be found in Appendix B.

Results of User Performance Tests Using Nintendo Joy-Con

Questions	Score
"I was comfortable with the interaction form in both tests"	3.75
"I had full control when marking the cubes during test 1"	3.00

Result Times of User Performance Tests Using Nintendo Joy-Con

Test subject	Time (s)
TS1	9.70
TS2	9.37
TS3	9.52
TS4	10.09
Average time	**9.67**

"I felt well-orientated during test 1"	4.25
"It was easy to mark all the cubes in test 1"	3.75
"I had full control of when marking the cubes during test 2"	3.50
"I felt well-orientated during test 2"	4.25
"It was easy to mark all the cubes in test 2"	3.75
Total score	**3.75**

Touchscreen - iPhone 7

Next, the touchscreen input was to be tested. In order for this to work a C# script had to be written to convert the touch inputs into the x and y values of the mouse. In this test, a left drag on the screen would result in the right rotation of the camera, thus allowing the user to move the red marker in the middle of the screen and point at the cubes. Presented in the tables below are the results of the survey regarding accuracy when touch input was used as the main type of user interaction. The device used for testing was the iPhone 7 where the user would use their fingers to move around in the view.

Results of User Performance Tests Using iPhone 7's Touchscreen

Results Times of User Performance Tests Using iPhone 7's Touchscreen

Questions	Score
"I was comfortable with the interaction form in both tests"	3.25
"I had full control when marking the cubes during test 1"	3.00
"I felt well-orientated during test 1"	4.25
"It was easy to mark all the cubes in test 1"	3.50
"I had full control of when marking the cubes during test 2"	3.00
"I felt well-orientated during test 2"	4.00
"It was easy to mark all the cubes in test 2"	3.00
Total score	**3.43**

Test subject	Time (s)
TS1	11.27
TS2	15.46
TS3	24.84
TS4	10.90
Average time	**15.62**

Gyro Sensors - iPhone 7

Accessing the gyro sensors in the iPhone 7 used in the test was done by C# scripts. The rotational values of the gyro sensors were converted into mouse movements in order to rotate the camera. This approach made it possible to simulate augmented reality, where the real world environment where created by computer graphics in Unity3D. Presented in the tables below are the results from the survey regarding accuracy when gyro sensor input was used.

Results of User Performance Tests Using iPhone 7's Gyro Sensors

Questions	Score
"I was comfortable with the interaction form in both tests"	4.75
"I had full control when marking the cubes during test 1"	4.50
"I felt well-orientated during test 1"	4.75
"It was easy to mark all the cubes in test 1"	4.50
"I had full control of when marking the cubes during test 2"	4.75
"I felt well-orientated during test 2"	5.00
"It was easy to mark all the cubes in test 2"	4.50
Total score	**4.68**

Results Times of User Performance Tests Using iPhone 7's Gyro Sensors

Test subject	Time (s)
TS1	8.33
TS2	5.60
TS3	7.33
TS4	10.60
Average time	**7.97**

4.3.2 Post Survey Interview

As a final part of the survey regarding the accuracy, the test subjects were asked to answer a general question about the different types of user interactions. The question reads: "What is your general thoughts about the different types of user interactions" and "What type of interaction did you feel the most comfortable with?".

The concluded answers are presented as follows:

Test Subject 1:

- Using your own device made for an increased pleasant experience. The touch responsivity in this prototype could be improved. I would like to sit with my own device much more than an external joystick which feels unmodern.

Test Subject 2:

- The touch responsivity was the hardest to handle since it lagged somewhat. However, it felt more intuitive than using Joy-Con. It felt more natural dragging the finger that to steer with a joystick. Using the gyro sensors worked very well. It was a smooth experience where one could tilt and turn the phone to find a different point of interests which felt intuitive. Both touch and gyro had respectively benefits because they feel familiar to an experienced smartphone-user.

Test Subject 3:

- All three types of user interactions worked fine. Using the Joy-Con was ok, touchscreen worked the worst and using the gyro was the best alternative.

Test Subject 4:

- The gyro interaction was the easiest and most fun to use. Might have been a bit sensitive. It would be exciting to be able to look around in 360 degrees. The Joy-Con was ok to use but is in the long term cumbersome and old fashioned to use remote control. The touch control could have been better if it was better implemented, not as fun to use as with gyro sensors.

Since the most promising type of user interaction was the gyro sensors according to the results, this was chosen to be the primary interaction method in the augmented reality view developed in the second iteration of the prototype. To ease navigation in situations where the Point-of-Interest (POI) is situated behind the passenger geographically, touch functionality was added which allows the passenger to swipe on the screen to find the POI rather than turning the entire device around.

4.4 Implementation of Multiple Views of User Interaction

The second iteration of the prototype was developed with a more wholesome inflight entertainment map application in mind. Based on the accuracy results conducted in the first iteration of the prototype and the results of the survey regarding improvements in today's inflight entertainment system, the second iteration of the prototype was developed. In this iteration, touch navigation was added in order to navigate different menus and retrieve information regarding the simulated flight "Paris - Singapore".

The second iteration of the prototype was intended to show the most requested information by the subjects participating in the first questionnaire, see appendix. One should note that the city names used in the prototype did not correspond to the actual cities that exist on this specific flight.

4.4.1 Start View

When a passenger is first introduced to the inflight entertainment map application it is important to answer the most requested information regarding the current flight. In the Start View, the passenger is introduced with an interactive globe, city of departure and arrival, a zoom button for zooming in and out on the globe and alternatives for navigating to different views. In order to not overwhelm the passenger with too much information, only the city of departure, arrival, and flight-time remaining is presented in this view. Rather than presenting all requested information by the subjects of questionnaire one, a conscious decision was made to spread out the information in different views. This approach allows for a more minimalistic view containing the most requested information. The Start View in the second iteration of the prototype can be seen in figure 28.

Figure 28. "Start View".

4.4.2 Magic Window - Country View

The "Magic Window - Country View" was accessed by clicking on "Magic Window View" and presents an interactive augmented reality view representing cities within the current country of the flight route. This view is the second iteration based on the results of the user performance tests made in prototype one. The user is presented with a marker in the middle of the screen used for marking points of interests by tilting the device. Signifier used in this context is the pointer used by e.g Google Cardboard applications [33].

Navigation is carried out by using the gyro sensors of iPhone 7 used to simulate augmented reality. In addition, touch navigation was also implemented in this iteration in order to support rotation angles impossible to do with gyro sensors.

In order to receive information about cities passengers are flying over, the passengers have to tilt the phone and thereby selecting the preferred point of interest. When hovering the marker of preferred point of interest, an "infobox" is animated into the window, see figure 30. Clicking on the info button locks and focuses the camera on the selected city. The click triggers an animation that presents information and the alternative to play a video about the selected city. When the user has read the information regarding the city, clicking on the "back sign" activates the navigation, unlocks the camera and animates away the information about the selected city.

The main reason for this interaction approach is to give the passengers further ways of how to interact with cities along the flight route. In addition, by simulating augmented reality this prototype would give an insight into the future use of the augmented reality approach.
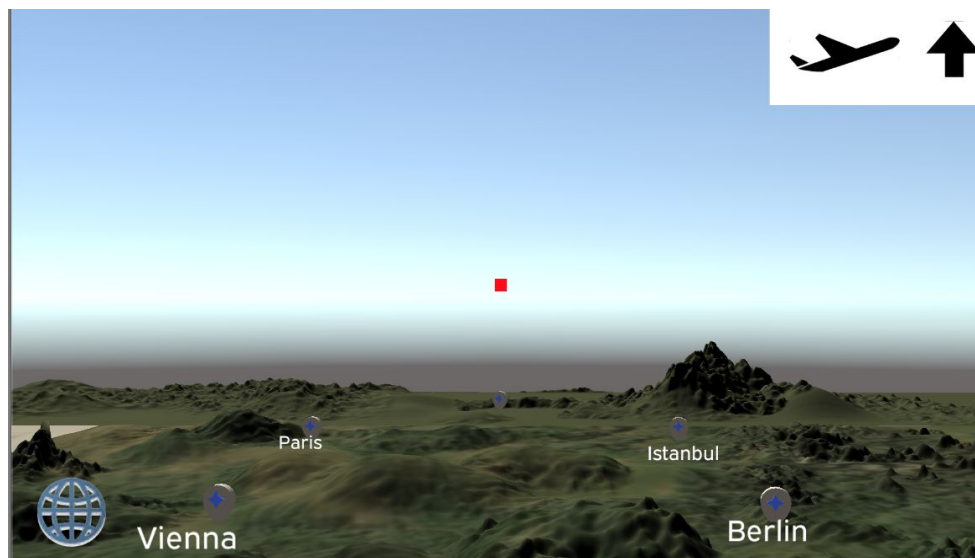
Figure 29. User perspective of "Magic Window View - Country View".

Figure 30. The user have marked "Vienna", an info button appears.

Figure 31. Information about the selected city.

4.4.3 Magic Window - World View

"Magic Window - World View" was similar to "Country View" but at a simulated higher altitude. The view presents information about current countries instead of specific cities. The same navigation mechanic was implemented in "World View" as "Country View" to ease the learning curve for users. Navigating in an augmented reality environment would allow for a less information-dense environment where only geographical information is limited to countries.

The same navigation mechanics as "Country View" are implemented in this view which lowers the level of knowledge the user needs to know in order to navigate this view. "World View" did offer a different perspective as given by the "Start View" with the purpose to further explore the different countries that the flight includes.
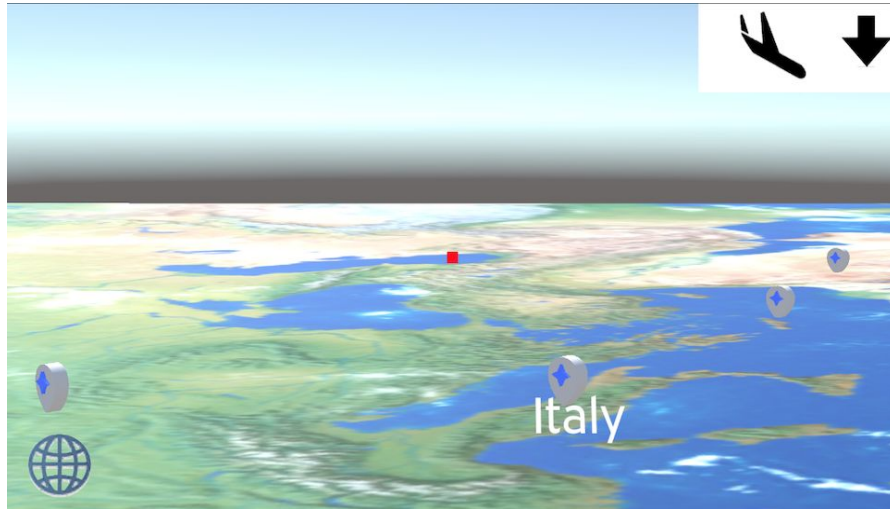
Figure 32. "Magic Window - World View".

4.4.4 3D View

The 3D View presents a 3D perspective of the current flight where the camera can be rotated around the aircraft. This view allows for less user interaction compared to "Magic Window View" which offers different ways of interacting with geospatial data. The view consists of an info button in the utmost left corner which presented the general information about the flight (altitude, speed, time to destination, local time, weather and temperature), a moving compass for a better sense of direction and interactable cities along the 3D terrain. Receiving general flight information was done by clicking the info icon, see figure 33. When clicked, the camera was rotated downwards in order for the info text to not cover up the aircraft.

For information about a specific city along the 3D terrain, the user simply rotates the camera by dragging on the screen and then clicks the name of the preferred city, see figure 34. Offering different alternatives of navigation were important for a large number of reasons. For instance, passengers with cognitive and/or muscular disabilities would have an alternative view with much less need for precision regarding the use of gyro sensors in "Magic Window View".
The terrain texture used in the "3D View" does not represent the actual terrain used in the flight route Paris-Singapore.
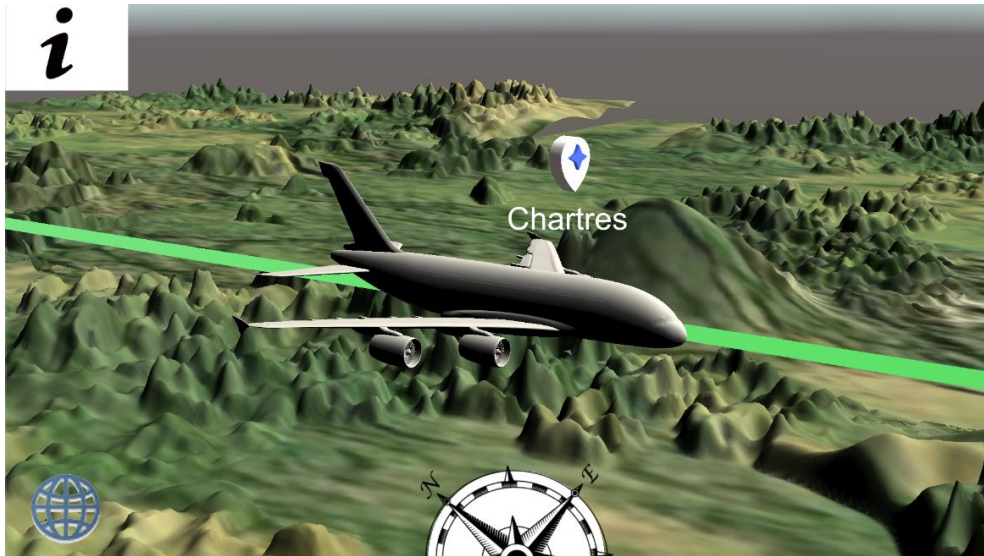
Figure 33. "3D View".

Figure 34. Info-button pressed.

Figure 35. "Paris" pressed by the user.

4.4.5 Flight Info View

The "Flight Info View" was implemented to present the most requested information by the respondents of the questionnaire issued early in the thesis process. Accessed from the Start View, the Flight Info View presents the flight information in a minimalistic manner for people rather having minimalistic user interaction. Having "Flight Info View" as an option in "Start View" made it available for quick access for users that request the most essential information about the flight. Figure 36 shows the "Flight Info View" in the second iteration of the prototype.

Figure 36. "Flight Info View".

4.4.6 Test Data

In order to get a sense of the overall user experience navigating in the second iteration of the prototype, a number of user tests were conducted. First, a number of tasks were compiled used to measure the usability of the current version of the prototype. These included mundane information-finding tasks which were to be used often in a commercially released product. Times to successfully finishing the results were recorded.

   The tasks and their corresponding subtasks can be found in the appendix. Next, the test subjects were asked to fill out a System Usability Scale (SUS) questionnaire consisting of 10 questions. In addition, test subjects were interviewed for a more qualitative result. Test subjects for the second iteration of the prototype were renewed after the tests of the first iteration of the prototype with a total number of participants of 4. The tasks that the test subjects performed can be found in Appendix D.

Result of the Time Needed to Finish Each Task

	Task 1 (s)	Task 2 (s)	Task 3 (s)	Task 4 (s)	Task 5 (s)	Task 6 (s)	Task 7 (s)
TS5	5.95	10.13	9.76	11.42	12.99	8.67	3.80
TS6	4.39	17.80	9.17	21.06	10.82	12.52	6.12
TS7	3.83	4.32	7.01	19.50	5.12	10.85	6.22
TS8	9.17	3.83	14.40	7.04	6.16	8.38	4.65
Average times	**5.84**	**9.02**	**10.09**	**14.76**	**8.77**	**10.11**	**5.20**

Task 1 - Preview Location of Departure and Destination in Start View

The task of previewing location of departure and destination in Start View had a very low frequency of error. Some of the less occurring but consistent user errors were rotating the globe too quickly which resulted in a lower sense of control. However, this sense of control later increased when the test users were used to the sensitivity of rotating the globe. Besides the misjudgments of sensitivity, no errors occurred.

Task 2 - Zoom In and Out in Start View

Zooming in and out in Start View had some varying results. This was due to the universal zoom in touch interfaces, "pinch and zoom" which were not implemented in this particular prototype. Instinctively, half of the test subjects tried "pinch and zoom" before noticing the magnifying glass with a plus sign on it. The pinch and zoom feature is thought being fully implemented in the third iteration of the prototype.

Task 3 - Find Information About Vienna, Austria in "Magic Window - Country View"

The task of navigating in "Magic Window - Country View" had no particular issues. Some of the users had a short learning experience due to the nature of using the gyro sensors and later had no issues navigating. However, one of the test users had issues with correctly focusing on the city of Vienna which lead to the info button going in and out of view.

Task 4 - Find Information About Italy in "Magic Window - World View"

Navigating to "Magic Window - World View" did result in some user errors of finding the button leading to the World View. In one instance, the test subject tried to tilt the phone in an upwards position. However, the test subjects quickly recognized the "plane up" symbol in the right-hand corner which triggered the view transition. While in the "World View" the subjects applied the same navigation mechanics which lead to a fast result when trying to find information about Italy.

Task 5 - Navigate to "3D View"

The task of navigating to the 3D View while in "Magic Window - World View" had a low frequency of error. One of the test subjects had difficulty in finding the Start View button since due to confusion in what the button represented. The "Start View"-button had similarities to the "Change language"-button found in other interfaces. When transitioning to the Start View none of the test subjects had a problem finding the "3D View"-button.

Task 6 - Find Information About the Current Location and About Paris

Finding information about current location went flawlessly since all test subject agreed on that the "i" symbol in the left corner would give an answer to the given task. Secondly, finding information about Paris challenged the test subjects to find ways of interacting with the touch display. However, all test subjects tried to rotate the camera around the plane by dragging their finger on the display. This was the correct way of interaction which leads the users to get Paris visible on the screen. One of the test subjects had a problem to align the city in view due to high sensitivity in the touch implementation. When users had Paris in sight, all of them tried to click the name which was the correct way of interaction.

Task 7 - Navigate to "Flight Info View"

The final task of navigating to the "Flight Info View" had a low frequency of user errors. However, one of the test subjects had to ask what specifically was asked due to the many sources of flight information in the prototype. The task was explained further which resulted in a better comprehension of the test subject which successfully executed the task in a fast manner.

System Usability Scale Questionnaire

In order to get a measurement of the usability of this iteration of the prototype, a System Usability Scale form was used. Calculating the usability score is performed by using the following steps, where the TS stands as the given score of the test subject and P for the points of that question [30].

Questions with uneven numbers: $P = TS - 1$
Questions with even numbers: $P = 5 - TS$

Points with uneven and even questions are added separately for each test subject and then multiplied with 2.5. In order to evaluate the result, the following limits are standardized:
-   80.3 points or higher implies an excellent grade of usability
-   Around 68 points imply an OK grade. There is room for improvement. Above 68 points is considered to be above average, under 68 points is considered below average.
-   51 points of lower imply a failed grade of usability. Big improvements can be applied for further improvements.

The following table presents the results of the SUS questionnaire. The SUS questionnaire used in the survey can be found in Appendix C.

Results of the SUS Questionnaire

	1	2	3	4	5	6	7	8	9	10	Total SUS points
TS 5	5	2	4	1	3	2	4	2	4	1	80
TS 6	4	3	3	3	4	2	4	2	5	2	70
TS 7	4	1	4	1	5	3	5	4	5	2	80
TS 8	4	1	5	1	4	1	5	1	4	1	92.5
Average Score											**80.63**

Post Questionnaire Interview

The following section presents the test subjects result of the final interview questions after completing the SUS questionnaire. These questions were constructed to give a clear indication if eventual hardships using the prototype were experienced.

Post Questionnaire Responses

Question	Test subject answers
"Did you need any more hints on how the system works?"	TS5: "I tried to pinch to zoom with my fingers at the Start View but it did not work. I did not receive any hints about that Magic Window used gyro sensors. TS6: "I did not know how to get back from the 3D View" TS7: "Some more hints needed in order to get information about the cities" TS8: "No, all the symbols were easy to understand and follow"
"Which part was hardest to understand?"	TS5: "Nothing special" TS6: "Go back from the 3D View" TS7: "Pointing at the cities while maintaining a fixed position" TS8: "The rotation of the globe at the start view was a bit fast"

"How easy was it to find the information requested from the tasks?"	TS5: "Very easy" TS6: "Easy, hard to do any error" TS7: "Very easy" TS8: "It was very easy, "i" symbol is a well-recognized symbol for information"
"Did you find it hard to find information regarding flight information?"	TS5: "No" TS6: "No" TS7: "No" TS8: "No, this approach offers a more fun solution"

4.5 Implementation of Suggestions of Improvements

The third iteration of the prototype was based on the results of the test data in the second iteration of the prototype. Issues regarding visual feedback shown in the tests conducted in the second iteration of the prototype were addressed and taken into consideration. Moreover, new ways of user interaction in the "Start View" and "3D View" as suggested by the test subjects were implemented in the third iteration of the prototype.

Focus on increasing the intuitive design was a priority during development. Minor issues such as finalizing animations were also made. The following section describes the improvements made in the third iteration of the inflight map application prototype.

4.5.1 Pinch and Zoom Functionality

The third iteration of the prototype presented a fully supported pinch and zoom functionality in comparison with the first iteration. This approach made it easier for new users that are not familiar with the zoom buttons and made for the universal implementation of the zoom functionality. In addition, when the user has zoomed in, the names of smaller cities emerges which allows for a more detailed view. Adding a pinch and zoom functionality increases the level of intuitively for new users of the prototype.

4.5.2 Signifier of Augmented Reality in Magic Window View

Feedback from some users mentioned the lack of instructions when entering the "Magic Window View". In order to improve the intuitiveness of "Magic Window View", instructions on how the user would interact with the system were implemented. Incentives on implementation of signifiers when

augmented reality is activated were based on user tests in the second iteration of the prototype and from theory (see section 2.4.2) regarding consistency in touchscreen interfaces. Due to users previously limited experience of using gyro sensors in order to simulate augmented reality, implementing signifiers was an important consideration. Updated symbols of the symbols for transitioning to "World View" and "Start View" have been applied instead of what the screen in figure 37 shows.

Figure 37. A signifier of enabled augmented reality.

4.5.3 Highlighting Point-of-Interests (POI)

Increased feedback when navigating was one of the more requested features from tests of the second iteration of the prototype. In order to address this issue, a glowing highlight effect when the marker had marked a Point-of-Interest was implemented. Applying a strong feedback loop is essential for intuitive design. It further supports the theory regarding visual feedback mentioned in section 2.4.2. Implementation of the transitioning info button reached a certain level of visual feedback. However, since the visual focus was in the middle of the screen, some users in the tests of the second iteration of the prototype didn't fully acknowledge the transition of the info button. Increasing the level of visual feedback when aiming for POI:s was a natural improvement in the third iteration of the prototype.

Figure 38. Point-of-interest gets a highlighted glow when marked.

4.5.4 Renewed Button Design - World View

Due to confusion regarding the transition to the World View, a new button design was introduced in the third iteration of the prototype. Making the button mediate a simple message as possible, the text "World View" with an augmented reality symbol was added. Incentives for this design approach was the results of the tests carried out in the second iteration of the prototype. Some of the test subjects had a hard time finding the button transitioning to the world view due to its design. Evidence of this issue can be seen in the increased time it took for users to perform task 4, "navigate to World View".
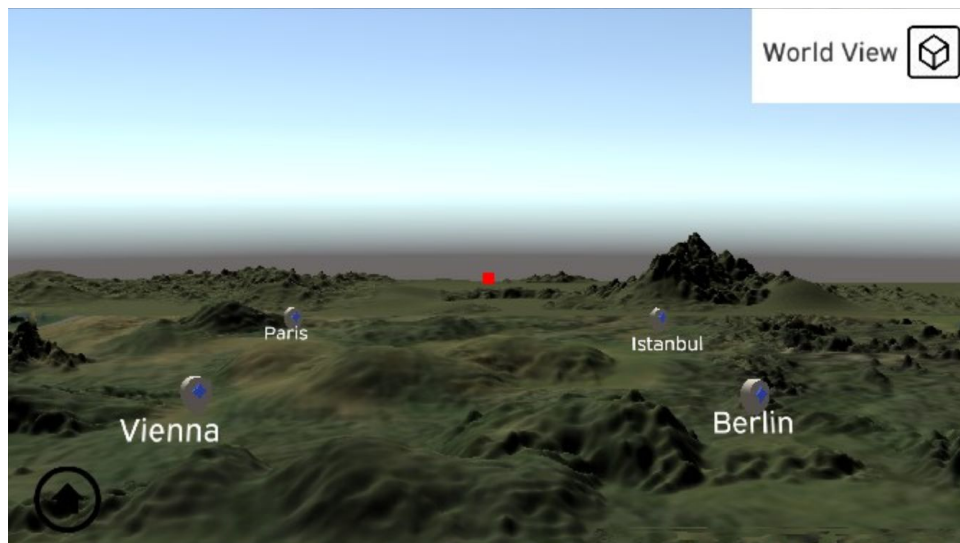

Figure 39. The text "World View" replaced the previous symbol indicating the transition to "World View".

4.5.5 Visual Button Feedback

Meeting requirements of visual feedback as mentioned in 2.8.2 was implemented in the third iteration of the prototype. When a user touches a button in the interface, each button changes temporarily to a green color. This further increases the visual feedback that the button actually has been pressed. Users in the second iteration of the prototype experience some confusion regarding whether if the button had been pressed or not.

4.5.6 Indication of Position - 3D View

The previous implementation of the 3D View had no specific indication of the current position of the aircraft. Addressing this issue was made by adding a "position-indication line" under the aircraft. The white line represents the distance that the aircraft has traveled, the grey line represents the remaining distance of the flight. The specific design was inspired by major map application providers (eg. FlightPath3D), further increasing the sense of location [34].

In addition, the compass feature was moved to the down right corner. The reasoning for this was to increase the visual space of the user. Previously taking up a major section of the screen, the compass is now less of a visual issue but still provides information regarding orientation.
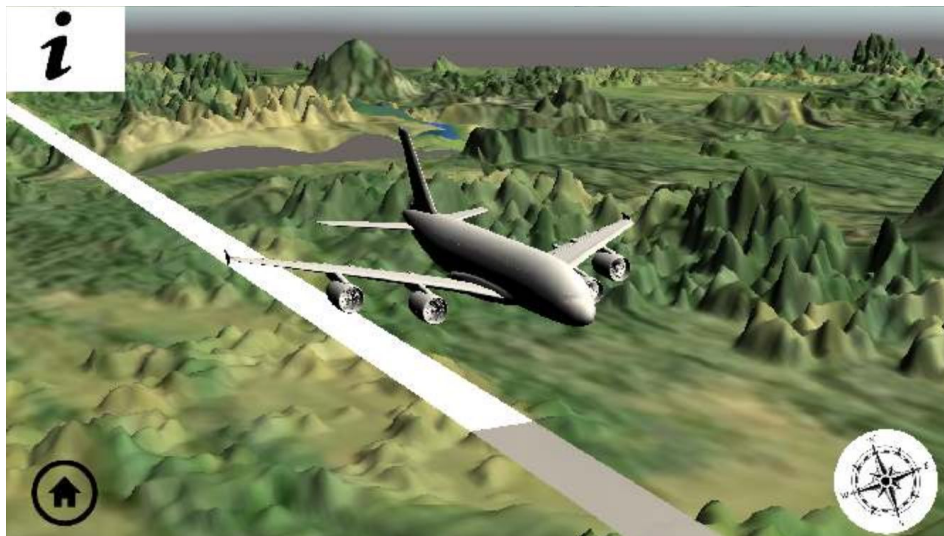

Figure 40. "Position-indication line" under the aircraft.

4.5.6 Test Data

In order to evaluate eventual improvements regarding result-times of user tasks, task assignments were carried out with the third iteration of the prototype using the same tasks users had to do in the second iteration of the prototype. Specific tasks and their corresponding subtasks and acceptance levels can be found in the appendix. The resulting scores lie between the values of 1 (strongly disagree) and 5 (strongly agree) based on the Likert Scale [30]. Following are the results carried out using the third iteration of the prototype:

Result Times to Perform Each Task

	Task 1 (s)	Task 2 (s)	Task 3 (s)	Task 4 (s)	Task 5 (s)	Task 6 (s)	Task 7 (s)
TS9	4.83	4.03	8.07	8.69	2.26	12.13	2.03
TS10	4.10	3.24	6.72	14.83	2.60	10.38	3.63
TS11	3.92	2.46	15.32	9.88	3.10	22.29	1.82
TS12	1.70	2.52	9.70	13.92	1.01	7.50	1.46
Average times	**3.64**	**3.06**	**9.95**	**11.83**	**2.24**	**13.12**	**2.24**

SUS Scores

	1	2	3	4	5	6	7	8	9	10	Total SUS points
TS9	3	1	5	1	4	1	5	1	5	1	92.5
TS10	4	2	4	1	4	1	3	2	4	1	80
TS11	4	1	4	1	2	1	5	1	5	1	82.5
TS12	5	1	4	1	4	1	5	1	5	1	95
Average Score											**87.5**

Answers of Test Subjects of the Post Questionnaire

Question	Test subject answers
Did you need any more hints on how the system works?	TS9: "No, it was very easy" TS10: "No" TS11: "No" TS12: "No"
Which part was hardest to understand?	TS9: "Zoom-functionality was a bit fast" TS10: "Sensitive navigation in some views" TS11: "Nothing special" TS12: "The touch functionality"
How easy was it to find the information requested from the tasks?	TS9: "Very easy. A big "i" is the universal sign for information" TS10: "Relatively easy" TS11: "Pressing the POI in "Magic Window View" instead of "i" felt more intuitive" TS12: "Very easy"
Did you find it hard to find information regarding flight information?	TS9: "No, it was very easy. When there's only a small number of buttons it becomes easy to navigate and find information fast" TS10: "No" TS11: "No" TS12: "No"

5. Discussion

This chapter discuss the results received from the three iterations of the prototype. Moreover, a discussion of general improvements of both implementation of the prototype and improvements of the methodology are submitted.

5.1 Touch Responsivity

When designing the first iteration of the prototype used for evaluating different types of user interaction, comments from the subject suggested that the touch implementation was somewhat delayed. Further investigation online showed that many Unity developers experienced lagging when their touch implementations were executed on devices running Unity Remote 5. When comparing this issue on different devices with varying processing power, it showed that touch responsivity had a direct correlation with the processing power of the device. However, the tests of the first iteration of the prototype showed that the test subjects preferred touch control over the remote control and still had relatively good control when marking the cubes in test 1 and 2. Since touch navigation is massively used in smartphones, the test subjects had the necessary experience to counteract the lacking of touch responsivity.

Additional observations regarding the touch implementation showed that different test subjects had different initial degrees of swiping angles. This effect showed to present in both the start view and the 3D view where touch navigation was the sole interaction. By simply decreasing the sensitivity, the issue was fixed. Due to the positive user feedback (aside from the touch responsivity), I decided to keep touch implementation in "Magic Window" in combination with gyro navigation. This approach allowed for easier rotation due to the limitations of the capability of gyro angles.

5.2 Gyro Sensors

When brainstorming about different ways of user interaction, thoughts of using Virtual Reality (more specifically Google Cardboard) were seriously considered. However, after realizing the environment of an aircraft the idea of using VR was scrapped mainly due to the risk of motion sickness [35]. After studying alternatives for VR, the alternative "Magic Window" was considered which allows users to view 360° content without a VR headset. This approach made it possible to remove the factor of motion sickness and instead simulate an augmented reality environment. One of the benefits of using Unity3D and Unity Remote 5 was the option to fetch the accelerometer data (gyro sensors) of any device that was connected, either from Android or iOS. The high accuracy of the accelerometer from iPhone 7 made it possible for a natural sense of control navigating in the "Magic Window View".

Communicating that the gyro sensors were the primary way of navigating was a challenge when designing the application.

5.3 Nintendo Joy-Con

Simulating an IFE remote control with the Nintendo Joy-Con made for an interesting result. During the user performance tests performed on the first iteration of the prototype, 8 navigation directions were implemented. However, many IFE remotes only have four navigation directions which don't correlate with the Joy-Con used. Furthermore, the Joy-Con helped to get an estimate of the user experience with a device similar to remote controls. The results from the first iteration of the prototype showed (even though the Joy-Con had more navigation directions) that the Joy-Con was in the least favorable of the three studied user interactions. On the basis of the test result, one can with confidence state that remote control is not suitable for navigating in a 3D environment. In addition, some of the test subjects suggested touch implementation during the tests with remote control due to the level of awkwardness.

5.4 Potential Economic Aspects

The approach of migrating IFE map applications on mobile devices might have some potential economic benefits. By offering a mobile map solution, passengers would simply download the application and get access to all information about the current flight. Benefits such as reduced hardware costs for the airlines would be important to take in consideration. In addition, a highly competitive market for smartphones results in further improvements in processor power. This in return would lead to devices that take advantage of technologies such as augmented reality, not possible with inflight hardware that is updated rarely.

The answers received from the questionnaire regarding the overall experience of the IFE map application suggested a positive attitude towards the use of passengers own devices. Users are most comfortable when using their own devices.

5.5 The Third Iteration of the Prototype

The third iteration of the prototype was based on intuitive issues discovered in the second iteration and improvement suggestion from my supervisor at Tactel. In addition, some of the improvements were directly linked to issues that emerged in tests of the second iteration. Tests regarding the usability of the third iteration indicated improvements compared to the results gathered from the second iteration of the prototype. This was based on the average result of 87.5 SUS score in the third iteration compared to a SUS score of 80.63 in the second. Implementing a higher level of visual feedback in combination with a more intuitive design yielded an improvement in both times of tasks performed.

The total time of tasks performed in the third iteration of the prototype was 46.08 seconds compared to 63.79 seconds in the second iteration of the prototype. Moreover, a better SUS-score acted as evidence for an improved prototype regarding suitability. The importance of a clear and intuitive interface design became very evident as the result of the tests were gathered. Regarding the "Magic Window View", some of the subjects had some level of difficulty of pressing the "info" button that slides in when the marker hovers over a point-of-interest. Suggestions of simply touch the point-of-interest would make it more intuitive. However, due to dual user input (gyro and touch sensors), this approach had some issues regarding the camera rotation in Unity 3D. When a user touches the screen, it registers the position of the first touch and calculates the distance to the position where the touch is released (the user lifts the finger). If an accidental touch causes the user to miss the indented target, the camera would register the touch as a movement and rotate the camera accordingly. Using a dedicated info-button prevents the risk of accidentally rotate the camera where a press of the info buttons directly locks the POI in view and present information about preferred POI.

Furthermore, regarding the "3D View", some of the test subjects experimented with potential interaction such as zooming out and in using multiple fingers. Some users found the correct interacting within seconds with rotation affected by sliding one finger side to side in a horizontal manner. This was a clear indication of users previous experience when interacting with touchscreens.

Regarding the methods used in this project, a different approach could have changed the outcome of the final iteration of the prototype. After the brain storming session and idea generation, the first iteration of the prototype was developed. Due to the complexity of the tests conducted in the first iteration, this lead to production of a hi-fidelity version of the prototype. Instead of focusing on development of a hi-fidelity iteration, focus should have been on developing a lo-fidelity prototype. A lo-fidelity prototype would have identified potential design issues early in the process, allowing for quicker iteration cycles and thus generating an more agile environment. Developing a lo-fidelity prototype in the second iteration would also be more effective, allowing for identification of issues regarding user experience.

5.6 Potential Improvements

Improvements regarding the third iteration of the prototype are several. Due to time limitations, several design ideas did not make it in the third iteration of the prototype. Showing an animated preview of the flight was a possibility but required much time developing in Unity 3D. In addition, as mentioned in feedback received from the third iteration of the prototype, implementing a more intuitive design regarding the marking of POI in "Magic Window View" could be improved simply by the user touching wanted POI. This implementation is far from impossible but would require valuable time in terms of delivering a functioning prototype.

Furthermore, regarding the design of the 3D terrain of the "3D View" and "Magic Window View", applying real map data that corresponds with the actual flight route would increase the sense of realness in the third prototype.

Regarding the methods used in this project, a different approach could have changed the outcome of the final iteration of the prototype. After the brainstorming session and idea generation, the first iteration of the prototype was developed. Due to the complexity of the tests conducted in the first iteration, this lead to production of a hi-fidelity iteration. Instead of focusing on development of a

hi-fidelity iteration, focus should have been on developing a lo-fidelity iteration. A lo-fidelity prototype would have identified potential design issues early in the process, allowing for quicker iteration cycles and thus generating an more agile environment. Developing a lo-fidelity prototype in the second iteration would also be more effective, allowing for identification of issues regarding user experience. Development of the second iteration of the prototype also took a large portion of the time resulting in a limited time of conducting tests. By letting tests subjects interact with a lo-fidelity version of the second iteration of the prototype, issues regarding the intuitiveness of navigating different views would have been shown and thus eliminating the need for improvements of the hi-fidelity version.

Regarding test subjects participated in the performance tests, a higher number of test subjects would have resulted in a more accurate representation of the user experience. Increasing the number of test subjects might have changed the level of usability in contrast to the actual result presented. Furthermore, by including test subjects with a more varying degree of touchscreen experience, a more accurate result of the user experience would have been achieved. The low number of test subjects was mainly caused by time limitations during the thesis work.

Moreover, the survey regarding the overall user experience of IFE map applications had a large number of experienced flyers. This might have affected the result regarding improvements of IFE map applications where suggestions were somewhat advanced (eg. have the speed in knots instead of km/h) and might had looked different if suggestions of improvement came from a less experienced target group.

5.7 Outlook

Future implementations of inflight map applications are hard to estimate with precision. However, due to the large interest of augmented reality applications in recent years, one must not exclude the potential of mobile augmented reality in inflight map applications. Allowing passengers to explore their geographical environment by interacting with their own devices would further increase their overall flight experience.

6. Conclusion

This section presents the conclusion of the thesis work. Summarization of the concluded results and discussion will be presented in the following section.

This thesis has evaluated the suitability on using mobile devices as complements in IFE map applications of today. In addition, the main focus has been to evaluate different types of user inputs in regards to the most suitable used in an IFE map application. Mobile augmented reality has been one of the more studied types of user interaction where multiple iterations with corresponding user tests have given valuable results. Adopting a user-centered design made it possible to study the user experience in each iteration of the prototype.

Adding questionnaires with additional interview questions in each iteration of the prototype allowed for collecting qualitative and quantitative data. Hence, drawing conclusions of potential improvements for future implementations was of considerable value. The tests conducted resulted in a positive user experience regarding the approach of using augmented reality in potential (real) future map applications. Moreover, realizing a mobile IFE map application in future implementations was encouraged by the test subjects indicated throughout the conducted tests. Many were positive to the new way of utilizing mobile augmented reality.

Regarding potential improvements, implementing a more reliable touch implementation is to consider. In addition, allowing a more smooth functionality in terms of selecting a Point-of-Interest in augmented reality settings could be improved further.

Making the inflight map application accessible for all types of user groups, one has to consider the vast majority of passengers with disabilities. This thesis has evaluated the suitability of augmented reality based on a mobile platform where tests subjects have had no physical or mental disabilities. However, studies regarding augmented reality with consideration of accessibility within the inflight map application would further expand the results presented in this thesis.

Regarding the goal of studying the suitability of an augmented reality based map applications running on personal devices as mentioned in section "1.3 Purpose and Goals", the results of the final iteration of the prototype indicated a positive user experience. However, it should be mentioned that the device used for testing was iPhone 7 with a specific screen size does not cover all types of devices that passengers might use when in flight. Conducting user performance tests with different screen sizes and devices would have increased the level of certainty regarding user experience.

Issues regarding touch sensitivity were one of the more common suggestions of improvement in the final prototype. In addition, implementing a more smooth orientation with a less sensitive gyro sensor in the magic window views was suggested.

Furthermore, evaluating the benefits of using the passengers own devices compared to the hardware offered by airlines had some difficulties due to limitations regarding testing of an actual IFE map application running on physical hardware. However, testing of mobile augmented reality running on iPhone 7 indicated a positive user experience and proved the potential of utilization of augmented reality in mobile devices. Increased user interaction within IFE map application was the most common suggestion of improvement according to the first survey.

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Appendices

Appendix A

Forms for data collection used during the pre-study phase

This form is designed to study the overall user experience of IFE map applications used today. IFE map application is the screen you can interact with during long flights. The study is a part of the pre-study of my thesis work focused on user interaction with IFE, more specific the map application. Note that you will remain anonymous if you don't take part in the interviews.

Age?

(Single selection)

- ❏ 20-25
- ❏ 26-35
- ❏ 36-50
- ❏ 50+

How often do you fly?

(Single selection)

- ❏ 0-1 times/year
- ❏ 2-3 times/year
- ❏ 4-5 times/year
- ❏ 6+ times/year

Do you have previous experience with IFE-navigation?

(Single selection)

- ❏ Yes
- ❏ No

What kind of remote did you use to interact with the IFE?

(Multiple selections)

- ❏ Built-in remote
- ❏ Touchscreen
- ❏ Separate tablet
- ❏ Other

Did you receive any information of value during the flight?

(Multiple selections)

- ❏ Flight-time remaining
- ❏ Distance remaining
- ❏ Geographical information

- ❏ Points of interests around the current location
- ❏ Altitude
- ❏ Speed
- ❏ Other

Did you experience any dissatisfaction when interacting with the IFE map application?

Long reply text

What's your improvement suggestions regarding IFE map applications used today?

Long reply text

Would you use the opportunity to use your own device as a complement to the IFE map applications of today?
(Single selection)

- ❏ Yes
- ❏ No
- ❏ Maybe

Would you be interested in engaging in interviews as a part of my thesis-work regarding user interaction of IFE map applications?
(Single selection)

- ❏ Yes
- ❏ No

Appendix B

User Performance Survey

I was comfortable with the interaction form in both tests

Strongly disagree   X   X   X   X   X   Strongly agree

I had full control when marking the cubes during test 1

Strongly disagree   X   X   X   X   X   Strongly agree

I felt well-orientated during test 1

Strongly disagree   X   X   X   X   X   Strongly agree

It was easy to mark all the cubes in test 1

Strongly disagree   X   X   X   X   X   Strongly agree

I had full control of when marking the cubes during test 2

Strongly disagree   X   X   X   X   X   Strongly agree

I felt well-orientated during test 2

Strongly disagree   X   X   X   X   X   Strongly agree

It was easy to mark all the cubes in test 2

Strongly disagree   X   X   X   X   X   Strongly agree

What are your general thoughts about the forms of interaction?

Long reply text

What form of interaction was you most comfortable with?

Long reply text

Appendix C

System Usability Scale - Survey

I think that I would like to use this system frequently.
Strongly disagree   X   X   X   X   X   Strongly agree

I found the system unnecessarily complex.
Strongly disagree   X   X   X   X   X   Strongly agree

I thought the system was easy to use.
Strongly disagree   X   X   X   X   X   Strongly agree

I think that I would need the support of a technical person to be able to use this system.
Strongly disagree   X   X   X   X   X   Strongly agree

I found the various functions in this system were well integrated.
Strongly disagree   X   X   X   X   X   Strongly agree

I thought there was too much inconsistency in the system
Strongly disagree   X   X   X   X   X   Strongly agree

I would imagine that most people would learn to use this system very quickly.
Strongly disagree   X   X   X   X   X   Strongly agree

I found the system very cumbersome to use.
Strongly disagree   X   X   X   X   X   Strongly agree

I felt very confident using the system
Strongly disagree   X   X   X   X   X   Strongly agree

I needed to learn a lot of things before I could get going with the system
Strongly disagree   X   X   X   X   X   Strongly agree

Appendix D

Tasks for test subjects to perform

Task	Sub-task	Accepted when
1. Preview location of departure and destination in Start View	1. Use finger to rotate the globe 2. Rotate until the text "Singapore" and its location is visible to the subject	The subject can clearly see the name of the destination and location.
2. Zoom in and out in Start View	1. Click on the magnifying glass with a plus sign 2. Click on the magnifying glass with a minus sign	The subject has successfully zoomed in and out the globe.
3. Find information about Vienna, Austria in "Magic Window - Country View"	1. Click on "Magic Window View" 2. Center marker on Vienna by tilting the phone (using accelerometer of the smartphone) 3. Click on the information sign sliding in. 4. Read the text. 5. Click on play icon with text the text "Play Video About City".	The subject has read information about Vienna and played video.
4. Find information about Italy in "Magic Window - World View"	1. Click on "plane up" symbol in the upright corner of "Magic Window - Country View" 2. Center marker on Italy by tilting the phone (using accelerometer of the smartphone) 3. Click on the information sign sliding in. 4. Click on play icon with text the text "Play Video About Country".	The subject has read information about Italy and played video.

5. Navigate to "3D View"	1. Click on the globe symbol in the down left corner. 2. Click on "3D View" in the down right corner.	The subject has received information about the current location and about Paris.
6. Find information about the current location and about Paris	1. Click info sign 2. Click back symbol 3. Use finger to rotate the camera to see "Paris" 4. Click on the text "Paris"	The subject has successfully found information about the current location and about Paris.
7. While in "3D View", navigate to "Flight Info View"	1. Click on globe icon down in the downright corner 2. Click on "Flight Info View" in the down right corner	The subject has read the flight information provided in the "Flight Info View".