Evaluating game experience when using augment reality

In real time strategy games

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Abstract

**Context.** Augmented reality (AR) is a technology that uses the camera to display what is seen on the screen and adds digital information over the picture. This study analyses how augmented reality might affect game experience when applied to real time strategy games.

**Objectives.** Evaluate the available development tools, to implement the game prototype and the AR interaction. Then develop interactive methods for AR and traditional version. Create a basic artificial intelligence, design the experiment to evaluate game experience, completion time and score.

**Methods.** The experiment were executed after implementation of the game, in this the participant played both the traditional and augmented reality version of the same game. Before starting to play participant filled out a pre inquiry about their previous experience with games, tablets and computers. After playing they answered a post inquiry with questions about the game. The comparing experiment was conducted with several participants in a controlled environment.

**Results.** The results show that most participants thought that the AR version had an interesting mechanic and that the game experience had been enhanced when compared to the PC version. However the participants thought the controls where better on the PC.

**Conclusions.** The results indicated that the game experience based on player performance, decreased in the AR version and that the controls were better on the PC. The participants thought that the PC version was a little easier to play. However about 71% of the participants thought the game experience on the AR version was interesting because they could move around while playing. The most enjoyable version of the game varied a lot between participants, having a slight preference for the PC version of the game. However, participants manifested an interest in playing a sequel of the game in the AR version.

**Keywords:** augmented reality, interaction techniques and game experience.
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Chapter 1

Introduction

Chapter 1 offers an introduction to the concept of augmented reality (AR), the problem formulation and the scope of this research.

1.1 Context

The use of cell phones and tablets has made new technology accessible for almost anyone that can afford it. Most modern mobile devices have built in sensors and cameras. For instance, the Samsung Galaxy Note 10.1 SM-P605, has an LCD display, two cameras one front facing camera and one rear facing camera. It also has an accelerometer, a gyroscope, a proximity sensor and a compass\(^1\)

The term augmented reality was introduced in 1992 in the following way: “This technology is used to augment the visual field of the user with information necessary in the performance of the current task, and therefore we refer to the technology as augmented reality (AR)” (Caudell and Mizell 1992). The technology can be used on a range of devices including cellphones and tablets. It uses the camera to display what is seen on the screen and adds digital information over the picture. AR has been applied to video games before but not many contributions have focused on combining AR with real time strategy (RTS) genre. Therefore, it will be interesting to combine this technology with RTS games. This technology may have the potential to enhance the game experience by adding some interesting interactive functionality to the game.

1.2 Problem

This work investigates how the AR technology can be applied on a RTS game and how it is affecting the game experience. Not many novel ways to interact with RTS game has been tried, the RTS games are usually developed for PC and therefore use mouse and keyboard. The interaction techniques with augmented

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reality on a tablet can be different compared to a desktop or laptop computer. Because it is not needed to use mouse and keyboard with a tablet for example.

Consequently, the problems are:

- How to apply AR technology to RTS games.
- Determine what type of interaction techniques that can be implemented with AR on mobile devices.
- How to measure and verify if using new interaction techniques is affecting game experience.

1.3 Relevance

With AR technology, RTS games created on for example a tablet have a new way to be played. Instead of using a keyboard and mouse in front of the computer, a person can move the tablet around while playing. The virtual added elements are overlaid on the real environment and displayed on the tablet. This may enhance the game experience for RTS games bringing the gaming closer to reality. This is important because it will show if this new way of playing RTS games can improve the current game experience. It will also show how to make it work by developing a RTS game for AR.

The purpose was thus to find out how this novel way to play RTS games could be implemented and observe how it would affect game experience. It has been found out by implementation and experimentation. Tablets have bigger screen than smartphones therefore it has been easier to develop an interface that not gets in the way for the game view. That also makes it possible to use almost the same interface on the traditional version on PC and AR version on tablet. Therefore a tablet was chosen as the platform for the AR.

1.4 Identification of gap

Previous contributions have applied AR technology to different game and interactive applications, it will be further discussed in chapter 2. However, not many contributions have focused in the use of AR as an interactive method for strategy games, giving this the opportunity to further expand the research on this field.

1.5 Aim and objectives

The aim of this project is to design and develop interactive methods that may enhance the game experience by applying augmented reality to real time strategy
Chapter 1. Introduction

To make games it is also necessary to design some kind of challenge. For RTS games this can either be a multiplayer mode or by playing against the computer. To play against the computer a game artificial intelligence (AI) needs to be created to make a computer player.

Therefore the objectives are the following.

- Select the available development tools, to implement the game prototype and the AR interaction.
- Design the RTS game and decide it goals.
- Develop two prototypes of the game, one traditional for PC and one AR version for the tablet and implement the interactive methods for AR and traditional version in the game.
- Create a basic game AI.
- Design the experiment to measure game experience, completion time and points in the two prototypes of the game in a controlled environment.

1.6 Research questions

How can augmented reality affect game experience in terms of player performance, enjoyment and interaction mechanics in real time strategy games?

Interaction mechanics refers to the ease of play like, how difficult the game mechanics are and its ease to control.

1.7 Structure of the thesis

The structure is as follows. In chapter 2, a literature study has been done to illustrate when augmented reality first was introduced and when the word first was defined. It is also to illustrate how other AR projects has been done, both in general and how it been used in games earlier. Also, it gathers several contributions in the area of applied AR to games, in order to have a better understanding of the current state of the art. In chapter 3, the method used in the project will be described, how the experiment will be executed, designed and set up. In chapter 4, the requirements and design to implement the game will be explained. In chapter 5, the technical details about the implementation are described. It will also show the resulting game. The results from experimentation are then
displayed in chapter 6. An analysis from the obtained results will be shown on chapter 7. Finally in chapter 8, conclusions, answering of the research question and future work is made.
Chapter 2

Related Work

2.1 Augmented reality

As previously described in the introduction the term augmented reality was introduced in 1992 (Caudell and Mizell 1992). AR adds digital information over the real world on a display (Mohring et al. 2004; Henrysson et al. 2005).

Even if the word was introduced 1990, the first research about augmented reality was in 1968 (Sutherland 1968). Sutherland invented a head mounted display that made the use of virtual reality possible but also augmented reality because the head mounted display were partially see trough.

There are two common types of AR, one marker based and one markerless. A marker based AR uses some identifiable object for example a sheet of paper with a pattern. A markerless identifies an object from the real world instead of using a marker. One of the first AR marker was done in 1995 where they used colour coded markers to display context aware information on top of a video feed (Rekimoto and Nagao 1995).

There has been previous research done about augmented reality and also game prototypes that implements the use of different peripherals.

Some of the previous contributions includes audio tour guide on museum using audio augmented reality (Bederson 1995). Instead of using a linear tape as the tour guide which can cause distraction when visiting a museum together, this tour guide activates when the visitor walks close to a pieces and solves that problem. The visitor carried around a modified music player that was activated by infrared when close to the pieces.

In 1999 a conference system is created overlaying virtual image on the real world (Kato and M. Billinghurst 1999). In this system the user had see trough glasses. It was possible for the user to draw on a virtual whiteboard located on a real board with six markers. The whiteboard were shared with remote users that had
a more traditional desktop system. There was also another type of marker that displayed a live video of a remote user.

Sightseeing on a cultural location by using AR (Vlahakis et al. 2001). The AR image were overlaid on the original cultural location, for example on a temple ruin location. A 3D temple model of the original temple was overlaid on the ruin trough a handheld device.

A system to translate text by using optical character recognition (Haritaoglu 2001). It is explained that user with help of a handheld device with a connected camera selects the text on the handheld device that it wants to translate. Then the system translates the foreign text into the users own language. Then it displays the translation over the foreign text on the handheld device.

In 2005 a driving simulator were created to support the drivers attention with AR (Tonnis et al. 2005). The car had a head-up display in the windshield that could display information. The intention was to make the driver more aware of where to look. It displayed an arrow or position of where the immediate danger was located.

A research about precise touch interaction on handheld devices has been done in 2012. Were they compares two different interaction techniques to make the interaction when touching the screen easier when using AR. One is called “the Freeze-Set-Go Technique”, it take a still picture and let the user interact with that without updating the camera view. The other is called “the Snap-To-Feature Technique”, it snaps to features in the camera view to improve the interaction, and the camera view is also updated at the same time. (Lee and Mark Billinghamurst 2012).

2.2 Augmented reality in games

There has been different contribution in which AR has been applied to video games. One example of this is AR-Quake (Piekarski and Thomas 2002). Instead of using keyboard and mouse to control the game, the player position in the world were changed by walking in the real world, a GPS were used to send the current position to the computer. The virtual game objects were overlaid the real world in the head mounted display. Therefore the player had to carry around a backpack, packed with a GPS and computers. Nowadays the player could carry a phone or tablet instead because it have things like GPS built in, like Galaxy Note 10.1 SM-P6051.

Chapter 2. Related Work

Another contribution about augmented reality that explore playing styles in the real world or on computer. They have implemented an AR version of the game Worms to examine the playing styles (Nilsen et al. 2004). A large table were setup between the players, that each wear a head mounted display with a web camera attached. The virtual content from the game is merged with the view from the web camera and displayed on the head mounted display. The player used a handheld device to select weapons and interact with the worms.

There are also other ways AR can be used, one that use head mounted displays with see through glasses in a racing game (Oda et al. 2007). A custom control was developed that had markers on it and the player holds it like a handlebar. It is used for controlling a car in the game. The map consists of a physical game board with markers all over it. Obstacles that the player need to avoid when driving appears on pre set location on the game board.

Another is where they use markers to construct a game scenario (Luz et al. 2008). A path between four markers are created that a 3D character runs along and displayed on a computer screen. If the user moves the markers the path is recalculated.

Also Rössler implemented a game on the first Iphone to discover the problems and possibilities by using AR games on this phone (Rössler 2009). A multiplayer shooting game were developed were the objective is to shot the other teams players. The players had a marker on their front and back that the player were supposed to point at and press a button to shoot.

There is also research about physical interaction between real and virtual objects, where they have made a small proof of concept game to demonstrate plausible interaction between real and virtual objects, in the game engine they describe (Namee et al. 2010).

Eubanks implemented a game to catch fireflies on an Android phone with the aim to draw people outdoors (Eubanks 2011). The game generates virtual fireflies within a certain radius around the player, this is then displayed on the smartphone display. To know the position of the player the game uses GPS, that also means that the player need to play the game outdoors. When the player gets close enough to a firefly the game enters a capture mode. In this mode it is possible for the player to capture the firefly by cupping the proximity sensor on the phone. The captured fireflies are placed in a live-wallpaper lantern.

In RTS games real time refers to that it is possible for the player to play at the same time as the opponent. The last word “strategy” means that skills have
to be used to win the game usually by conquest but sometimes also by other means like exploration or trade depending on game. (Rollings and Adams 2003)
Chapter 3

Method

In this chapter details about the method that was experiment will be explained in section 3.1. Then experimentation setup in section 3.2.

3.1 Experiment method and its design

The experiment has been conducted in a controlled environment, discussed in section 3.1.1. The participants for this study were selected according to the following criteria: they needed to have previous experience with RTS games and know how to use a tablet or smartphone. Tablets and smartphones are regarded as similar because the main difference is in screen size. The participant needed to be able to handle mobile devices, computers and writing to be able to answer the questions, thus an age range of 19 to 25 was decided. The participant also needed to be healthy enough to be able to walk, sit and play the game. The participant could be any gender.

The evaluation has been conducted as Benyon et al. (2005) describes. To evaluate the participants previous game experience with RTS games and get their initial thoughts on the genre, a pre inquiry has been made. The participants filled in a questionnaire to answer this before starting to play. Then play a tutorial to learn one version of the game. After the tutorial, play the game, while being filmed and also asked questions. Then repeat the tutorial and gaming in the same way with the other version of the game. Then a post inquiry has been done where the participants will need to fill in a questionnaire with some questions about the game experience. Each question has been compared to see if participants think the experience has been enhanced or not and if the interaction was better or worse. The questions given are displayed in the figures in chapter 6.

The video recording of the participants while playing showed if there was any major change in game experience. The video will indicate how different participants reacts to the game. It also showed if they stayed focused while playing. The post inquiry contains questions with specific answer choices and a few open question at the end. The open questions related to problems with game experi-
Chapter 3. Method

ence and interaction that affected the participant during play.

The time it will take for participants to test the game is about 30 min to 1 hour. Therefore the number of participants has been limited, because of the time aspects in this project. Data from the pre inquiry and post inquiry that each participant answered was collected with Google Forms. Expect for the wins, scores and time that was automatically stored to file after finishing the game.

3.1.1 Controlled environment

The environment has been controlled by having the computer, tablet and markers setup in the same way for each participant. The participants have not been disturbed during playing. Also there has not been any big distraction in the room. It was important that the AR version had good lighting, therefore the lamp in the room were always lit. There was some noise generated from the computer fans but there were no distracting noise in the room.

The equipment used for the experiment was the following.

- 1 Laptop, LG P310, with Windows 7 as the operating system. CPU, Intel Core 2 Duo P8700. GPU, Geforce 9600M GT. 8 GB RAM.

- 1 Mouse, Razer Deathadder 3.5G, connected to the laptop.

- 2 Tablets, Samsung Galaxy Note 10.1 SM-P605. CPU, Qualcomm Snapdragon 800. GPU, Adreno 330. 3 GB RAM. 8 megapixel camera that supports video recording in 1080p in 60 FPS.

- 1 Video camera, Samsung hmx-h200bp/edc. Supports video recording in 1080i in 50 FPS

- 2 markers, one for the tutorial level and one for the main level.

- 1 table to place the marker on.

3.1.2 Experimentation protocol

An experimentation protocol was created, in order to keep control over the experimental procedures. In short, it consists of the following parts. Counter balancing has been used so A and B may refer to tablet or PC version of the game. That means that the participants took turns which version of the game to start with. A and B can never be the same and will always be different for each participant.

- Preparing the room. Checking battery levels on tablets and other devices. Checking if memory cards have enough space left. Checking the volume levels. Clean up and restore the room if necessary.
• Welcoming the participant and explaining the research goal and the exper-
imental procedures to the participant.

• Give the participant the consent form and ask the participant to sign it. The consent form included information about the experiment and recording.
Also each participant were asked if it was okay to record them.

• Let the participant answers the questions from the pre inquiry.

• Start video recording A and let the participant play the tutorial of A version of the game, tell them to try to move around themselves and also move the tablet if A is the tablet version.

• Ask if they understood the tutorial. Show a printed map over the game. Then switch to the main level. Let the participant play.

• Stop video recording A

• Start video recording B and do the same steps for B.

• Let the participant answers the questions from the post inquiry.

• Discussion with the participant. In the discussion attention were especially paid to what the participant said about the experience they had with the game on both versions. Also some attention was paid to if they had any information about any RTS games for tablets or smartphones.

3.2 Experimentation setup

The experiment for the PC version is conducted in front of a computer and a tablet was used to record the participant while playing. The setup looked like in figure 3.1.
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Figure 3.1: The laptop that was used with a mouse connected. The tablet in the picture was used to record the participant while playing for further analysis.

The experiment for the tablet version of the game is conducted in a lab room that is well enough lit for the camera on the tablet to be able to identify the marker correctly, see figure 3.2. The markers frames have also been enhanced with LED-backlights to improve the tracking performance in low light condition. The LED-backlights was always turned on when doing the experiments even if the light in the room might have been good enough itself.

Figure 3.2: The tablet that the marker where placed on in a room with enough space to move around the table. On the table is the marker placed. The participant stands and aims the tablet towards the marker while playing.
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Figure 3.3: Video camera that can record the participant while playing the tablet version of the game.

(a) Marker for the tutorial level, one of the Vuforia example markers has been used. (b) Marker for the main game level, the marker is completely custom made.

Figure 3.4: Markers for the AR version of the game. The marker has been put in a frame to avoid damage and a LED-light strip for background light where installed. It was used to improve tracking performance in low light conditions.
Chapter 4

Requirements and design

In the following chapter 4 an explanation of the requirements and design for the project will be made.

To do the experimentation an implementation was required because there was not many game in the RTS genre found, which implemented augmented reality. Another requirement is that it should work on both a tablet and a PC, even if there are games that uses AR they usually only works on, for example, a tablet but has no PC version. The only option to be able to do the experiment, is to implement a RTS game working on both platforms.

4.1 Design requirements

The aim for the implementation was to build a simple RTS game. To do this, a study of commercial RTS games was done, looking at a replay or by actually trying the game, to see how the game usually worked. The implemented game needs to behave like a real time strategy game.

In many RTS games, buildings can be built with the resources that have been gathered. When buildings are complete they can construct new units. These units can then defeat the enemy. How a player builds and use its units decide if they win or not. However these games are usually created with a large team thus it would be too time consuming to do it alone. Instead it was decided that the created game should be simplified but still keep the strategy part. Instead of building buildings and gathering resources the player has to capture control points that directly generate new units. That means it is still a RTS game but can be played and implemented a lot faster.

The camera interaction required to behave like a traditional interaction system on the PC and required to interact with the marker on the tablet.

The AR has been the main focus and there are no other significant differences in the game mechanics between the versions.
Chapter 4. Requirements and design

It was required to implement a game play giving the player a goal to fulfil in the game. This also forces the player to interact with the game if they do not want to be defeated. To do this a choice was to implement multiplayer for two players or create an AI for a computer player. The choice made was to implement an AI because multiplayer may cause some practical problems when trying the AR version of the game. It would reduce the participants option for free movement around the marker.

Also for the experiment a tutorial had to be created to let the participant learn how to play the game.

4.2 Design

Before starting with the implementation, a game design document was created taking into account the requirements. This document shows how the game will work as a whole. Also some concept art where drawn to show the general look of the game. The different elements of the concept art showed the game content, like landscapes, buildings and units and also how the game would work. When this document and the concept art were completed, the implementation started.

4.3 Inspiration

The game takes elements of other RTS games. It is mostly inspired from the following science fiction themed RTS games. “Warhammer 40,000: Dawn of War” developed by “Relic Entertainment” and released in 2004. “Starcraft” developed by “Blizzard Entertainment” and released in 1998. “Dune 2000” developed by “Intelligent Games” and “Westwood Studios”, it was released in 1998.

In “Warhammer 40,000: Dawn of War” one of the resource is generated when capturing the control points. The gathered resources can be used to build units. The implemented game works the same, except that it skips the building unit step, instead the units are generated by capturing control points. Also if units are close to the control point, it is captured after 15 seconds, similar how it works in the Battlefield game series.

The traditional drag selection that generates a box as the player drags the mouse, to select units, usually works in almost the same way in all these RTS games. This drag selection box is used in both version of the implemented game. In the tablet version the players drags their finger on the screen instead of using the mouse. Also the game looks where partly inspired by all of the mentioned RTS
games.

In the traditional version the camera behave in a way common to most RTS games. The player drags the mouse to the edges of the screen to pan around. In the AR version a novel way was developed, it was decided that the landscape would be generated around the marker. This means that the player could drag the tablet around to pan around in the world as long as the marker was insight for the tablets camera. Because the marker were as big as a A4 paper the map size were limited and it was decided that a point of interest in the middle of the map were needed to always focus the players interest there and not too far out on the edges of the map.

4.4 Look and feel of the game

The game takes place in a unique science fiction inspired world, where grass, sand and trees have a blue tint where futuristic bikes, tanks and spaceship are common. In this world, laser canon is the most common weapon. It is to limit the modelling and texturing time to a relatively low level. The complete look of the finished level is shown in figure 4.1.

![Image](image_url)

**Figure 4.1:** Top down view of the map.

4.5 Sound

For the sound used the credits goes to the artists Celestial Aeon Project, Kazune Koyama, ciiciruc and Xytum for the different music used in the game. All music
used creative common license and can be found at http://www.jamendo.com. Also public domain sound were used for motor sound, explosion and laser shot.

4.6 Game objective

The game objectives is to capture the middle area on the map, this area is called “winning control points”. To capture the winning control point, the player needs to stay in the area for 30 seconds to capture it, and then defend it for 60 seconds to win the game.

4.7 Buildings and units description

The game has three kinds of buildings.

- Factory, located at the spawn point, all types of new units spawn in an area close to the factory. Each player has one factory.

- Control point, a control point is a point that can be captured if the player has units close enough.

- Winning control point, a control point placed in the middle of the map, which the player needs to capture to win the game.

The implemented game has three types of units bikes, tanks and spaceships.

![Game units](image)

(a) Bike  (b) Tank  (c) Spaceship

**Figure 4.2**: Game units. The units were modelled in the 3D software Blender

- Bike, is the weakest and most common units, the player gets a lot of these units. This unit cannot attack while moving.

- Tank, is a stronger and slower but quite common unit. Can attack while moving.

- Spaceship, is the strongest and hardest to get unit in the game.
4.8 Game play

Units are received all the time until a maximum number of units are reached. At the beginning the player only receives bike units. The player can capture control points to receive tanks or spaceships, if the player already has a control point of same type the player will get these units faster instead. The more control points the player control the easier it is to win.
Chapter 5

Implementation

The game that has been implemented is a basic real time strategy game created with help of Unity. In Unity it is possible to use C# or Javascript as the programming language. The target platform that has been used is Android for the AR version of the game, therefore, an android tablet has been used. The traditional version with mouse and keyboard input has been done on a PC. In the augmented version of the game, a landscape is generated around a marker that is placed on a table. The game will use a basic AI, created with help of a finite state machine.

The implementation has been limited to a simple RTS game. The implementation will also be limited to use only one marker for RTS games. Also the look of the interface has been designed for Galaxy Note 10.1 SM-P605 only, it will still run on other relatively new android phones and tablets but the different aspect ratios might make the game look incorrect.

The implementation was done using Unity as the development tool. Unity was chosen because it allows the game to be created in a short amount of time compared to implementing everything from scratch. Unity also offers an easy way to compile for both a PC and an Android platform. Only a small amount of platform specific code was required because of the different input methods.

For the AR version on the tablet, an AR SDK was needed. Several choices have been examined to see what can fit this project. One alternative for AR was OpenCV, but there was a cost for Unity integration, 95$, therefore the choice fell on Vuforia that had free Unity integration. Vuforia also has good documentation with many examples. Metaio was another choice for AR that was looked into, it is however now bought by Apple and all download links was removed. There are other AR SDKs as well but they did not have very extensive documentation. A website that had a extensive comparison between the different AR SDKs were used.¹

Except for Unity and Vuforia, other tools were needed to create graphics. The tools used for this were Blender to create 3D units and building. Gimp and Inkscape was used to create 2D graphics, like textures and sprites. Unity was used to graphically create a graphical user interface and a tree. MonoDevelop, that is included with Unity, was used for C# programming. All tools used are free of charge and some are open source. Also the Android SDK was used to create a Unity plug-in for vibrations for feedback when pressing buttons, because Unity only had built in vibration support that vibrated for 1 second. The created plug-in instead takes a time in millisecond that can be set directly from Unity when calling the plug-in.

When starting developing, it was noted that the frames per second (FPS) dropped to very low levels when using AR and graphics from the game at the same time. The game might not have worked at all because of the bad FPS, it was around 5 FPS. A lot was done to improve the situation, and now the FPS is around 30-40 when a level loads but might go down to 20-25 when the game progress. It felt like pushing the tablet to its limit. Even though the tablet used has one of the best technical specification in the market. It would probably be to slow to be playable if an older tablet had been used. There were some settings in Unity that improved the feeling of smoothness a lot even at lower FPS. This was figured out by much fps testing with the Unity profiler. Also some information about bad performance was found by reading in the Unity and Vuforia internet forums. To improve the situation even more, code improvements were done to increase the performance of the game, including Unity’s lists for units and buildings was recreated by C# lists for better controls and faster searching for objects. Also it was noted that one of my models had too many polygons, the situation was improved by using the Blender modifier, decimate, to reduce the polygon count. The low FPS count only apply to the AR version on the tablet, on the PC without AR the FPS was high enough even without the optimizations.

5.1 Interacting with the game

The camera control is the major difference between the traditional and AR version. On the traditional PC version the camera where controlled with the mouse by panning at the edges of the screen. On the AR version instead, the maps middle point where set by the marker and the player could drag the tablet around to move the camera.

In RTS games you play as the commander of your troops and the camera controls in the AR version where designed and implemented to be more like a real command table where the commander of an army could look at the map placed on the table and decide the next move for its army. In the AR version the player
will stand around the virtual command table, similar to a real one. Because of
this the in game map is a little bigger than the A4 marker, it is about as big as
a small table.

If the tracking is lost because the tablets camera does not see a part of the
marker, the map stops updating its position. However the game is still possible
to control, for example moving units in the visible part of the map. If this happens
the tracking can be returned directly by aiming the tablet more at the marker.
To avoid issues with this, it was explained in the first step during the tutorial
for the AR game prototype. How the participants react if this happens will be
explained in the video results.

Units selection was implemented in a similar way on tablet and PC. First the
player left click or touch the button “Drag select” depending on platform. This
enter “drag mode” where the player can drag a rectangle on the game terrain
by holding the mouse button or finger on the screen. When releasing the mouse
button or lifting the finger, the selection were created containing all units that
was inside the rectangle. After the units were selected it was possible to move
them by left clicking or touching the game terrain. The experiment focus was on
AR, therefore other controls where similar on PC and tablet.

A basic formation system was implemented for the units to behave in a better
way. Instead of letting all the selected units move to exactly the same position
in the game world, the positions where spread out in a specific way. The units
always use the same formation and the behaviour cannot be changed in-game.

5.2 Artificial Intelligence

A finite state machine was created for the computer player. An explanation how
this finite state machine works is made in the following text and complemented
by figure 5.1.
To win the game it is important to have enough units. Therefore the focus of the AI is to get units and then attack. The numbers in the following text refers to the states in figure 5.1. The spawn point “S1”, is close to one of the control point, it is captured automatically by units spawning in the area, this gives the computer player tank units. Because the control point close to “S1” is captured automatically, the AI begins by moving units from “S1” to capture control point “S2” to get spaceships. If this was a success it moves units from “S1” to capture control point “S3”, to get spaceships faster. After capturing was a success the AI start to move units from “S1” to winning control point “S4”. All the time checks is made to see if the AIs enemy, the human player, has captured the winning control point “S4”. If this happens the AI abort it current mission and moves all units on the map to the middle to try to prevent the human from winning. It returns to normal if the human player loses control over the winning control point “S4”.

5.3 Resulting RTS game

The game objectives, graphics and game elements are the same in both versions. The only difference is that the tablet version use other input methods, camera and visualization. This is to test how well the AR technology works for a RTS game. Figure 5.2 offers a in game screenshot of the resulting implementation of AR version of the game and photos from the game while playing. Figure 5.3
Chapter 5. Implementation

shows a screenshot from the resulting traditional PC version of the game.

(a) 
(b) 

Figure 5.2: Player playing the AR version of the game and aims the tablet towards the marker (a). Screenshots from the AR version of the game (b). The red round game logo in (b) shows that tracking of the marker is active, it disappears if tracking is lost.

(a) 
(b) 

Figure 5.3: Photo of the laptop used to play the game (a). Screenshots from the traditional PC version of the game (b).

Information regarding the score, time in seconds and winner, was stored in a file on the tablet or computer when the match ended. This was to avoid manually timing and checking every time the game ends.
In this chapter the results from experiment will be shown. By executing the experiment different results have been achieved. First the demographics and pre inquiry will be shown. Then score, time and wins for each participant will be presented. After that the results from the post inquiry will be shown. The average for each question is also presented and calculated by the following formula, where \( n \) is number of answers and \( a \) represent the answer choice, for example \( a_1 \) is the answer choice participant one made:

\[
\text{Average} = \frac{1}{n} (a_1 + a_2 + \ldots + a_n)
\]

### 6.0.1 Demographics

The aim was to get at least 15 participants. The goal was reached and 28 participants have taken part in the experiment. According to the formula by Niles:\(^1\)

\[
\text{Margin of error in a sample} = \frac{1}{\sqrt{\text{Number of people in the sample}}} = \frac{1}{\sqrt{28}} \approx 19\%
\]

The formula shows that margin of error has been about 19% with 28 participants. The age was between the set intervals, 19-25 years according to the method.

![Percent of males and females](image_url)

**Figure 6.1:** The participants consisted of 24 males and four females.

6.0.2 Pre inquiry

Results from pre inquiry follow. The participants had a set scale to choose how much they in general used the PC and tablets. 10 meant using the PC or smartphone/tablet at least one hour almost every day. 5 using it at least one hour once a week. 1 using the PC or smartphone/tablet at one hour once a year or less. Participants could also set something between 1 and 10. In figure 6.2 and 6.3 a convert table was used, to convert the values to approximate days per week. Based on the previous information, 10 equals to close to 7 days per week, 5 equals to 1 day per week and 1 equals to close to 0 days per week. The values in between was linear estimated based on this, the convert table looked as in table 6.1. Figure 6.2 shows that average usage days per week is 6.68 for PC and 5.22 for tablets.

<table>
<thead>
<tr>
<th>Answer choice</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days per week</td>
<td>7,00</td>
<td>5,83</td>
<td>4,67</td>
<td>3,50</td>
<td>2,33</td>
<td>1,00</td>
<td>0,75</td>
<td>0,50</td>
<td>0,25</td>
<td>0,00</td>
</tr>
</tbody>
</table>

Table 6.1: Convert table

![Graph showing usage days per week for PC and mobile devices.](image)

**Figure 6.2:** Approximation of the general PC and mobile devices usage per week.

This question in figure 6.3 show approximative how much the participants plays on PC and mobile devices every week. In average the participants used PC for approximate 5,4 days per week and smartphone/tablet for approximate 2,43 days per week.
In general how many days do you play games per week?

**Figure 6.3:** Approximation of the gaming usage on PC and mobile devices per week.

Figure 6.4 shows that all participants have played at least 2 RTS games before and 9 participants had played 10 RTS games or more before.

**Figure 6.4:** Amount of RTS games the participant has played before.

In average the participants took 10,786 hours to play RTS games each month, see figure 6.5. Some participant did currently not play much RTS games but had before.
Chapter 6. Results

Figure 6.5: How many hours the participants currently play RTS games each month.

6.0.3 Score, time and wins

Game time, scores and if the participant has won, was automatically saved to file. The result are shown in the figures 6.6, 6.7, 6.8, 6.9 and 6.10 and relates to how the player performs in the different game prototypes. The main goal was to win the game but the player could also get a score by destroying units and capture control points. How much points are given depends on how strong the units are and how important it is to succeed in the game. Destroying a bike gives the player 10 points, a tank 20 points and a spaceship 30 points. Capturing a standard control point gives the player 100 points and capturing the winning control points gives the player 500 points. Also if they win the game, they get an additional 1000 points. Most score is given when game is won because it is the main goal with the game.

The following diagrams will show participants completion time, the participant that won are in figure 6.6 and the participants that lost are in figure 6.7. The diagrams were split because if the participant was victorious a better strategy resulted in lower completion time, it means that lower time were better. However if the participant was defeated longer time meant that the participant strategy were good enough to be able to hold out longer against the computer, thus higher time were better in that case.
Figure 6.6: Completion time for participants that won.

Figure 6.7: Completion time for participants that lost.

Below the diagrams for score will be shown, it is split depending on if the participant was victorious in figure 6.8 or defeated in 6.9. When the participant were defeated higher score were better. However if the participant won, higher score is not always better, it depends on the completion time because the main goal is to win the game, thus winning is more important than score. For example, if the completion time for two participants is the same, then the one with higher score
performed better. The participants that lost had in average a little better score on PC.

The victorious participants, higher score is better if different players finish the game in same amount of time

Figure 6.8: Victorious participants score on both of the game prototypes.

The defeated participants, higher score is better

Figure 6.9: Defeated participants score on both of the game prototypes.
Chapter 6. Results

![Bar graph showing PC and Tablet win counts for all participants.](image)

**Figure 6.10:** Win counts for all participants.

### 6.0.4 Post inquiry

Results from post inquiry will be shown below after a description of the rating system used in the diagrams. The following figures 6.11, 6.13, 6.20 and 6.21 uses a rating system were the participant could answer between 0 and 10. In the figure description of each diagram it is explained what the highest and lowest values means. If the participant answer something in between 5 and 10 it means that the participant partly agreed to the highest value, higher values means agrees more to highest value. If the participant answer in between 0 and 5, it means they partly agreed to the lowest value, lower values means agrees more to lowest value. The result in 6.11, 6.12 and 6.13 relates to interaction mechanics in the game.

![Bar graph showing difficulty ratings for PC and Tablet.](image)

**Figure 6.11:** 10 the game was very easy, did not have any problems. 5 neutral it was some problems but still possible to play. 0 it was hard to understand and nothing worked at all.
In average the participants got 6.2 on tablet and 8.4 on PC as seen in 6.11. That means they in average thought the PC version was easier to play then the tablet version. The question refers to the game mechanics used in the game.

![Bar chart showing difficulty of controlling on PC and tablet](image)

**Figure 6.12:** 10 the controls and interaction with the game worked very well. 5 neutral, the controls were okay but can be improved. 0 the controls were horrible, nothing felt logical and impossible to play.

The question in 6.12 and 6.13 relates to how the interaction in the game worked. In average the participants got 5.9 on tablet and 6.9 on the PC. That means they in average thought the PC version had a little better controls than the tablet version. In average PC version had the best controls when participants were asked, see figure 6.13.

![Pie chart showing best controls](image)

**Figure 6.13**
As seen in figure 6.14, there were a small edge to the PC version when participants were asked which was most enjoyable. There were 13 participants (46.4%) agreeing that the PC was most enjoyable and 12 (42.9%) that agreed that tablet was most enjoyable, how much they agreed with each claim is displayed in figure 6.15 and 6.16.

**Figure 6.14:** Version of the game that the participants found as the most enjoyable.

**Figure 6.15:** Shows how much the participants agree that Tablet version was most enjoyable.
Figure 6.16: Shows how much the participants agree that PC version was most enjoyable.

As seen in figure 6.17 more participants answered that the tablet were the best. Also how much they agreed to each claim is shown in 6.18 and 6.19.

Figure 6.17: What the participants thought was the better interaction technique.
Chapter 6. Results

How much did the participant agree that the tablet was best, it was interesting to be introduced to novel interaction techniques to be able to move while playing

![Bar chart showing participant agreement on the tablet]

**Figure 6.18:** Which participants agrees and how much they thought that the tablet interaction technique was the better one.

How much did the participant agree that the PC was best, the control the participant got over the game was better on the PC

![Bar chart showing participant agreement on the PC]

**Figure 6.19:** Which participants agrees and how much they thought that the PC interaction technique was the better one.
In average the participants got 8.6. See figure 6.20. That means most participant thought the tablet version was an interesting new experience and no one said it was uninteresting but a few were neutral.

**Figure 6.20:** Shows if the participant thought it felt like an interesting new experience to play the AR version. 10: Yes, it was very interesting. 5: maybe/maybe not. 0: Not at all.

**Figure 6.21:** Shows if the participant thought the game experience has been enhanced when playing the AR version. 10: Yes, it has been enhanced a lot. 5: maybe/maybe not. 0: Not at all.
Chapter 6. Results

In figure 6.21, the average the participants got were 7.1. That means in average thought the experience had been enhanced. Also not all but more than half of the participant thought the experience had been enhanced.

When asked what version the participants wanted a continuation of the result showed that most wanted a continuation of both version and no one answered “none”. The results also show just a slight edge to the Tablet version, see figure 6.22

![Which version of the game do you want a continuation on?](image.png)

**Figure 6.22:** What version the participant wanted a continuation of.

6.1 Result from open questions and discussion with participants

The overall experience of the game was satisfactory. Participants found the game enjoyable, fun and showed motivation to play even more rounds that the ones offered in the experimentation. However, improvements to the prototype were suggested by the participants, focusing on improving controls, visualization, GUI elements and tutorial contents.

The reaction to the AR game experience were mixed, some said it were cool but there were also some returning problem the participants experienced. For example multiple participants said it was hard to reach for the edges of the screen on tablet because the tracking could be lost. Also multiple participants said it was heavy to hold the tablet after playing for a while. There were also a few that had trouble selecting spaceship. However the game was considered very smooth (not sluggish or bad fps).

The traditional experience were in general mostly satisfactory, most issues was related to not having the exact controls as they were used to. As there were some
complaining about having to deselect before being able to select units on the PC and some thought some key bindings where “missing” like controlling the camera with the “arrow keys” on PC or making groups with the “control key”. However there were a few that thought it was less straightforward to move the camera on PC and that the PC version felt a little lifeless because the missing AR camera interaction.

6.2 Results from video recording

The video recordings where stored on the computer for analysis. This showed the participants reactions when playing the game. All participants pay attention to the game on the tablet and PC. In general the participants reaction during play were not that many. Questions were sometimes asked during the tutorial, usually they had missed some of the information that was in the tutorial. A few said the tablet version was cool when trying it or more precisely when trying to move the tablet around. Some did not move even though all participants were told to try when playing the tutorial on the tablet. It was reflected in the questions in the post inquiry that they answered. Some talked more while playing then others, it could be reaction to how the game went, like if they felt overwhelmed by the enemies attack. Some also said at the end game “I will probably not make it” or “I am crushing them”, depending how skilled the participant were or if they had played one of the version of the game before and already learned some kind of strategy to beat the enemy. It was also seen that when some of the participants lost tracking and the map positions stopped to update, they directly moved the tablet to the previous position and the tracking returned. Then they tried to move the tablet or themself in another way that usually worked and not causing lost tracking.
Chapter 7

Analysis/Discussion

In this chapter analyses of the obtained results will be made, taking the inquiries, open questions and videos into account.

7.1 Analysis of scores and inquires

As seen in the results shown in figure 6.10, it was more participants that were able to win when playing on the PC. That may be that the AR version still needed to be developed further to make it more logical to play but it can also mean that people was not used to the AR technology even though all participants learned to play the game with the tutorial. The participants used smartphones/tablets and PCs for an average of over 5 days every week. They were playing games for an average of over 2 days every week. As seen in the pre inquiry. Some used the computer more and some used the smartphone or tablet more. Therefore it was most likely not a previous experience problem, instead it was most likely an issue with the controls of the AR version.

When the participants were asked about the difficulty of the game, no one answered with 0, meaning it was hard to understand and nothing worked. Instead based on the results in figure 6.11 participants answered in average 6,2 on the tablet version, which meant it was no major problems making it hard to play. Still the answer was even better for the PC version, where the participants in average answered 8,4. Thus it was easier to play on PC in general according to the participants. Only a few participants answered that it was easier on the tablet. The main reason for this was probably because of the possibility to lose the tracking on the AR version as seen in the open questions. The results also vary more for the tablet version. Maybe because the participant where not used of how to hold the tablet to avoid that kind of situation.

The participants were also asked about the difficulty of the controls on each platform. In general the participant thought the controls where better on PC, 62,9% of the participants according to figure 6.13. This may also be because of losing tracking on tablet version and might be the reason why the participants
thought the controls where better on PC.

The average for all participants when asked what version they enjoyed more, shows a small edge to the PC version, 46.4% compared to 42.9%. There were also participants that enjoyed the tablet version more, the results varied a lot. It was probably more enjoyable when everything works well and can also be related to the interaction with the controls. However someone that had a little less experience of RTS games seemed to enjoy the tablet version a lot more. Maybe the AR technology combined with RTS was for players less used to RTS or players that want a new kind of experience.

The participants were also asked which version the participants thought had the more interesting interaction. Sitting in a chair in front of the computer or walking around while playing the AR version. In general the participant thought the interaction where more interesting on the tablet, 71.4% compared to 28.6%. Probably it was because of the AR technology used, to be able to move around.

In general the participant wanted a continuation on both versions when asked, 50% gave that answer. Some wanted a continuation on the tablet version (28.6%) probably because it had an interesting concept and some wanted a continuation on the PC version (21.4%) maybe because of the controls. This show that most people thought both game versions where equally interesting.

Most participants (71.4%) answered that it was an interesting new experience to play with AR on tablet. Probably because it was different way to play RTS games compared to the usually in front of the computer.

Also when asking the participant if most of them thought the experience were enhanced when AR was used. It may was because they thought it was an interesting new experience even though the interaction with the controls where considered worse on the tablet.

In the discussion most participants said they did not know any RTS games for tablets and one thought it was strange that it was so uncommon because she thought the tablet was a good alternative for RTS games. However there were also a few suggestions about smartphone and Nintendo DS games that existed.

### 7.2 Analysis of videos

When analysing the video it was noted that some participants did not see the control points current colour, this was something that applied to both AR and Traditional version. Even though there were improvements made in this area
during implementation, the contrast may need to be increased even more.

The video recording showed that all participants where focused on the game while playing, both on the PC version and Tablet version. There was also interesting to see that even though all participants were told to try to move around the tablet and themselves when playing the tutorial for the AR version. Most did not try it and it was first at a later stage they figured out that it could be easier to see parts of the map while moving around. For example one participant that actually tried to move when told was surprised and said it was cool. He also moved a lot more than other participants while playing. There were also some other participants that moved around more while playing on tablet.

The participants that temporarily lost tracking moved the tablet to its previous position directly. Therefore the lost tracking did not affect the player performance much, but some participants may have thought it was annoying and could be a reason that they thought the PC had better controls.
Chapter 8

Conclusions and Future Work

8.1 Conclusion

Taking everything into account the game experience according to the research question was worse in some areas and better in others. The research question was “How can augmented reality affect game experience in terms of player performance, enjoyment and interaction mechanics in real time strategy games?”. For example it was more interesting when AR was used but the PC version had better controls. Most participants, 67.9%, thought the controls on the PC were better. This is a novel area for RTS games and there may be better ideas on how to implement good interaction using AR with RTS games so this probably needs further development. One participant gave a suggestion how to make the selection easier. Still most participants, 50%, also said they wanted a continuation on both versions, which means they may have thought the concept was interesting.

Some participants complained that the tracking was lost when reaching for the control points at the edges of the screen. That was probably one of the reason they thought the controls where better on the PC, it may be caused by not moving around enough, it is usually easier to stand at the other side of the table compared to the map to see that part of the map. To make it easier the player actually has to walk around the table. This also was directly reflected in the win count result, more participants were able to win when playing on the PC.

From this analysis it can be concluded that the game experience has been affected in different ways when using AR. When participants were asked most said that the experience where enhanced but probably not as much as the result from the question in figure 6.21 showed. A further conclusion is if the controls had been better the game experience would also increase. Another conclusion is that, if the players get more used to the AR technique, it can enhance the game experience. For example most people did not move much, they tried to play the game the same way as on a PC just standing, but the intention is that people should have to move to play, affecting the game experience in a better way.
From how the interaction worked compared between traditional and AR version, it can be concluded that the AR version controls still need to be improved. Also it can be concluded that the controls was better on the PC. There was however a few that thought it was better on tablet.

To answer the research question. The results show that the player performance decreased in the AR version, there were fewer participants that were able to win. Also the score the participants got where in average a little less for the AR version. The version they enjoyed more in general varied a lot but the PC version had a small edge in enjoyment in average. Also 71,4% of the participant thought it was more interesting to be able to move around when playing the AR version. It was also found that most participants thought the traditional version had better controls. When the participants were asked how difficult the game was in general, they in average thought the traditional version was easier but they did not find the AR version to be very difficult either, see figure 6.11. However there was a slight edge in wanting a continuation of the AR version of the game so it may be worth to further develop it 28,6% of the participants compared to 21,4%. 50% instead wanted a continuation of both versions.

8.2 future work

There were some problems with the interaction as seen in the results therefore it will be interesting to develop an improved interaction technique for AR. Maybe find a better technique do the selection.

Also it would be interesting if some development of a technique for AR using multiple markers. Maybe four markers could be used in each corner of the tablet. This may solve the issue about losing the tracking and it would also probably make larger maps possible.

A multiplayer mode could be developed to be able to play with other players either in the same room or different rooms. If playing multiplayer in the same room it needs to be taken into account that the other players can get in the way for each other.
Bibliography


BIBLIOGRAPHY


