GeoFort: Mobile Game for Motivating Physical Activity using Gamification and Augmented Reality

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Abstract

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With technology continuing to advance, a lot of everyday tasks are becoming easier to perform and less physically demanding. However, as a result of this, peoples lives are also becoming more sedentary. There is a need for motivating people to be more active.

The project’s solution to this problem was to develop a mobile game application which made use of Augmented Reality (AR) technology together with GPS to be able to set the outdoor world as the playing field. Along with using the science of gamification, we strove to create a gameplay that encourages players to continue to play.

The resulting game makes the player move outdoors to be able to progress within the game. This feature of the game counteracts sedentary behavior. The results suggest that the use of gamification is an important aspect of making a game that players find fun and motivating. The AR technology was less important and needs more functions than just being able to view 3D-models.
Sammanfattning


Projektets lösning till detta problem var att utveckla ett spel till mobiltelefoner som använde sig av Augmented Reality (AR) teknologi ihop med GPS för att sätta upp världen utomhus som spelplan. Tillsammans med vetenskapen om spelifiering, strävade vi efter att skapa en spelupplevelse som uppmuntrar spelare att fortsätta att spela.

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**Glossary**

**Augmented Reality (AR)** The technology Augmented Reality supplements the live moving real world with virtual 3D objects which are integrated by a computer in real time.

**friends list** A list of your friends in a game which can be contacted or invited to groups.

**gameplay** A term for describing all experiences a player encounters while interacting with a game. For describing the overall feel of a game excluding sound and graphics.

**gamification** The practice of adding and applying game elements in a non-game context.

**GPS spoofing service** An application that lets the user choose their position by GPS to show to different apps meaning the user can fake their location.

**intellectual property** Intellectual property (IP) refers to creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names, and images used in commerce. IP is protected in law by, for example, patents, copyright, and trademarks, which enable people to earn recognition or financial benefit from what they invent or create.

**SLAM** Simultaneous localization and mapping (SLAM) is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent’s location within it. This technology makes it possible for AR applications to recognize objects and to overlay digital interactive augmentations.
1 Introduction

With technology continuing to advance many everyday tasks are becoming easier to perform and less physically demanding [18]. Mobile phones are more powerful than ever which opens up for new uses of their technology. But the results of the advancing technology are not only positive. The impact it has on peoples lives can lead to a sedentary lifestyle. In order to prevent the increasing inactivity, new incentives to perform physical activity need to be created.

Our idea is to develop a mobile game application that will make use of Augmented Reality technology (AR) together with GPS to be able to set the outdoor world as the playing field. Also, we will acquire and use research and knowledge about the new research field gamification to create gameplay that makes people continue to play. If we can achieve this idea, we will have a game where people are active outside while having fun with a game.

The game is set in medieval times where the player commands an army and builds settlement forts. The forts are placed at coordinates in the real world where the player then can use AR to view their buildings in real time. One player can attack other players and conquer their forts. To be able to afford to build forts and retaining an army the player needs to collect resources. Those are acquired by moving in the outside world collecting them. Having all resources and forts spread out in the real world results in a lot of movement for the player in order to play the game. The goal of the game is to increase in level which unlocks new achievements, features, and upgrades for the player to use.

2 Background

The technology boom during the millennium shift has impacted our world in many ways. New innovative technology, that has evolved over the last decades, has created a reliance on devices and systems to decrease time and labor spent. The increased efficiency of modern technology, however, is not only positive. A decreased energy expenditure has been found in studies to contribute to progressive weight gain [18]. In order to reverse this effect, the article suggests promoting health-related exercise, particularly walking. It concludes: "Perhaps the function of “health-related exercise” might be to reverse the energetic impact of mechanization."

Since the integration of technology in many workplaces, the need for physical activity for many tasks has been replaced [3]. Along with the increased time spent doing sedentary activities such as watching TV, playing video games and browsing the web, the amount adults sit during the day ranges between 6-8 hours, shown in an article measuring US adults [26]. The effects of doing a sedentary activity such as watching TV can have serious complications on individuals health. An increased risk of both obesity, metabolic syndrome, and other metabolic risk markers can all be positively associated with sedentary behavior. [16].

Recent developments in children’s media usage in Sweden have however seen a decrease in time spent watching TV. In contrast, an increasing trend of playing video games both on computers or on tablets have emerged, to where 98% of young children between ages 9-12 regularly play games [29]. The reason for this is not stated, but the motivation and desire created when playing video games could contribute [12].

### 2.1 Gamification

The term gamification is the practice and application of game elements in a non-game context. The purpose is to extract and use the motivational power that video games can possess and transfer them to other areas [7]. It has been successfully implemented in contexts such as education, crowdsourcing, data-collection, health, marketing and more [24]. The results of using gamification can motivate users to increased user engagement and productivity [15]. The applications may extend to all areas where incentive and motivation are required.

### 2.2 Augmented Reality

Augmented Reality (AR) is a subset of Virtual Reality (VR) [1]. VR replaces the real world environment with a simulated one whereas AR supplements the real world with virtual 3D objects which are integrated by a computer in real time. It enhances the user’s perception of the real world and displays information the user cannot directly detect with his own senses. For example, with the help of a mobile camera, you can view a flying UFO hovering in your own backyard. The value of this technology is that it is not only a still picture but a live image that reacts to movement from the user. While it could be used in the implementation of games to create a better experience it does not only have entertainment purposes. It can also be used as tools to help in business and construction. One example of this is in home decoration where it is possible to render 3D models of furniture into a room to visualize how it is going to look.
2.3 Competition

To evaluate the current market, the web was searched for two types of mobile app games. Games with AR elements as well as training apps are viewed as competition for our game. Apps like Pokémon Go, Zombie Run! and Fitocracy have important features to study and improve. These apps are described further in the related work section. When it comes to apps in general we found, by comparing the most popular AR-games in the world with the 300 most popular games on Google Play Store, that very few games implement AR-technology. Pokémon Go was the only game that contains AR elements that were on the list. Therefore there is less competition when making an AR game.

2.4 External Stakeholder

The project is conducted with the video game company Fredaikis AB as an external stakeholder. Fredaikis was founded by a small group of people, with CEO Fredrik Sjögren’s initiative to develop a standalone modification to the open world zombie video game ”Infestation: Survivor Stories”. The modified game contained alterations to the gameplay, such as a global inventory where gained items carry over between different servers. Along with an effective anti-cheat system, the game peaked the interest of the original game publisher OP Productions LLC. With their permission, the game launched on the game platform Steam in November 2016 in the official Infestation series as ”Infestation: The New Z”, quickly reaching 13,000 concurrent players [28].

Since then, Fredaikis have developed the game even further, adding many features. Examples are a battle royale game mode where many players battle against each other to the last man standing and worldwide servers which allows more players globally. Now the company is looking to expand their business, developing new games and examining new areas to do so. One of these is mobile games with exciting game elements that can be developed with the company’s own or new intellectual property.

3 Purpose, Aims, and Motivation

Sedentary behavior could cause health problems for people who do not activate themselves in other ways. A study made in 2012 showed that sitting too much results in an increased mortality risk [21]. It is evident that there is a need for activation and re-enabling physical activity to prevent health problems. The purpose of this project is to help people with motivation for exercise.
In order to satisfy this need, the users need to find motivation and cause to exercise. Our project intends to use the elements of gamification to provide this. There are already cases where this has been done, with applications for mobile phones to track exercise and movement in order to motivate users. However, these apps seldom implement several game elements or elements rooted by research or science [15].

There exists games that succeed in getting people outdoors and moving [37]. But among the games looked at in this report, it seems to be a side effect of the game rather than having the game built around it. Here is where our game differs from these because we develop the application with movement as a core part of the gameplay. The project is also aimed at a younger target audience consisting of an age range between 10-30 years. As shown, children have an increasing trend for video games at 9-12 years which will set our lower limit to 10 years. Furthermore, the age statistics for the similar game Pokemon GO suggests that the age group 18-29 makes up the largest portion of players [27]. This will set our upper limit to 30 years. Because we want some creative freedom we chose the theme of the game ourselves. The game was set to be a war game in medieval time which made gamification elements easy to implement. This decision sets the target audience to people between 10 and 30 years old who likes war games.

The project aims to research the field of behavior and psychology around games. The game elements will be used to provide an incentive for players and motivate them to become active. This knowledge will be used to create a gameplay that makes the players want to come back. The resulting product from our research is a mobile game with a medieval setting which is designed to make people go places outdoors in order to play. Playing this game will benefit the player health-wise, which is aligned with our purpose.

To actually get users active, it is important that the user is not able to fake progress. To prevent this, the user’s position will be tracked by GPS. It is also important to enable our application on as many devices as possible. This is done so we can maximize the number of users being activated and general health benefits. Therefore we will strive to develop our application with other platforms in mind. Namely, the AR framework we will develop should be able to work with both iOS and Android programming environments. This ensures that for future work the application’s reach can be maximized.

Designing our application to maximize incentive and motivation could lead to users playing an excessive amount of time. It is also not our goal to have players play many hours the first couple of days and then stop playing after a week. We rather see them coming back over a long period of time while spending a short amount of time in the game each time. To encourage this, the first hour spent on the app each day will be more rewarding than the others. This can be achieved through for example having daily quests and having upgrades of your army taking one day to finish.
3.1 Delimitations

Due to time constraints, we have these delimitations:

- **Area of play is limited.** The area of play will be limited to a small specified area to make developing and testing of the app easier.

- **Basic multiplayer functionality and few social features.** Developing multiplayer and social features will require a lot of time. Because of this, there will only be basic multiplayer features like having the same playing field for all players. For multiple social features like chats and friends list, we need a server to handle communication between players. However, there will exist some social features that our system can handle.

- **No user customization.** The user will not be able to customize their character.

- **Few units and basic gameplay functionality.** The units the user can build will be limited and the gameplay will only have basic functionality.

- **No measures for personal security and safety for children.** We will not implement that forts and resources cannot spawn in an unsafe location. We will also not focus on protecting user data and information. Although those things are important if the game was to be released, this is not important for this version of the game.

- **Delimitations in AR-module.** There are multiple limitations to our Augmented Reality module. Ideally, we want to have a game object that would be aligned properly to the ground. This would be used using ground plane technology, which means that the ground would be recognized as a plane in the 3D space. However, the mobile phones used in this project did not support these features as a newer model is required such as Samsung Galaxy S9 [36]. Also, the AR-module chosen requires a license to support location-based AR which means that we won’t be able to get closer or further away from the object.

4 Related Work

There are many fitness and game applications who intend to provide motivation for users by gamification. However, few implement multiple game elements or root their gamification in research [19]. Augmented reality integration is also uncommon, and is often limited.
The game elements found in contemporary applications was found to rarely follow behavioral or psychological studies. One important element to provide an incentive for players to play the game is the social aspect. Having the users compete against each other will stimulate them and increase motivation to play the game [4]. This is achieved by implementing elements like multiplayer and rewards that can be showcased to others (e.g. leaderboards). Another element that has been found to be important is to have customization. Allowing the user to customize the appearance and style of their character as well as game elements increase their motivation to play the game [31].

4.1 Zombies, Run!

Zombies, Run! [38] is a mobile game using audio and story elements to get people running. It immerses players in a zombie apocalypse by using missions that need to be done by going to places in the real world. The players are sometimes chased by zombie hordes to motivate activity. However, the game is only single-player and does not have social features. It also does not have game objects or an interactive map. Our app implements multi-player elements and aspires to contain a social aspect with a friends list and chatting which according to gamification is important for motivating players.

4.2 Fitocracy

Fitocracy [11] is a fitness app implementing game elements and a social network to motivate and log users training. The game uses quests that reward experience points to the user when completed. The more experience points the user has, the higher level the user will be. Higher levels give achievements and badges that can be showcased to other players via the social network functionality. The logging is however completely done by users own account, so it is easy to fake progress. In our app, there are measures to make cheating more difficult such as tracking the player’s position and movement to ensure their progress. Also, the user has no way of giving inputs except playing the game.

4.3 Pokémon GO

Pokémon GO [22] is one of the biggest mobile games [5]. It prompts players to go outdoors and catch Pokémon via a modified game map. Resources can be bought with in-game currency or by going to locations. The game also features a basic AR-camera view that is triggered by proximity to a Pokémon. The game does have multipler
elements but players can not directly interact with each other, so social elements are not present. As mentioned above, we are using more social features to make the game more motivating according to gamification.

5 Method

This section explains the method and choice of technology for the application. We will present alternatives and motivate why we made our choices.

To develop the application we are going to need a:

- Mobile platform
- Map service
- Database for storing user and game information
- Game engine for Augmented Reality
- Augmented Reality Framework

5.1 Mobile Platform

We chose to develop our application on Android using Java. The alternative to this would have been iOS or React Native. Android has a market share of about 85% in 2017 which was one of the key reasons we chose Android since we wanted to make our app available on as many devices as possible [6]. We could have used React Native [9] to develop cross-platform and target even more devices. However, we wanted to create a native Android application. We also have experience coding in Java which influenced our decision.

5.2 Map Service

Since our application is heavily based on maps and GPS technology we chose to integrate Google Maps as our map. An alternative to this would have been Mapbox or another open source mapping platform. However, Mapbox is not completely free. Making a large number of requests to their server will start to cost money [20]. Google Maps
5 Method

is free for the Android API and has one billion global active users [13]. It is widely supported across platforms and is also customizable and has an easy to use API. Since it is also developed by the same company as Android we chose to implement Google Maps as our mapping platform.

5.3 Database

For saving and storing information we chose Firebase. Firebase is a mobile development platform developed by Google. Firebase has many other features such as Authentication and Cloud Messaging. These features will help with the social aspect of our app, allowing users to log in via social media and find their friends and communicate with them. Firebase is also a unified app platform which means it is supported on all mobile platforms and is scalable [10]. An alternative to Firebase would have been to set up our own online MySQL database. Since Firebase has other features such as Authentication and Cloud messaging which will help with our app development and because of time constraints we chose to use Firebase as our database.

5.4 Game Engine for Augmented Reality

For implementing Augmented Reality in our application we needed to use a game engine to render 3D objects. The engine had to be free and cross-platform. Two game engines that fulfills these requirements are Unity3D and Unreal Engine 4 [34] [35]. Since Unreal Engine is designed for demanding applications and larger games, it does not fit our purpose very well. This is because we will not simulate a large 3D world with a lot of objects, but rather a few objects in the view of the camera. Unity has the possibility to be exported to Android and is more suited for less powerful game devices. Therefore we will use Unity because it will be easier to implement in our project.

Unity supports 2D and 3D graphics and scripting using the language C#. There are also many frameworks available for it which can implement AR [32]. Since it is cross-platform, the devices we can reach are maximized.

5.5 Augmented Reality Framework

Vuforia is a framework for implementing AR applications that work on several platforms [33]. It is also integrated into Unity 3D which makes exporting to Android simpler. Vuforia has many features such as ground plane detection, where the ground is
recognized as a 3D plane, and SLAM. It uses mainly vision-based AR, which means using the camera for tracking where to place an object in relation to reality. An alternative would be to use ARCore, which is Google’s own AR framework that works natively with Android. However, it is still being developed and requires new technology found only in recent mobile phones. Therefore, we will use Vuforia instead to enable our application on more devices.
The Android application is the core of the system where the game is played and the player can interact with the world. The app contains the Google Maps module which can be seen in Figure 1. The Google Maps module is responsible for tracking the player and show them where they are in the world by using GPS. It is important for the game to know where the player is because resources such as wood, stone, and gold are placed
on the map. If a player is too far away from the resource it is unavailable to pick up. The tracking is also important for collecting the distance the player has moved. This is data that is used to complete missions and unlock achievements within the game.

![Augmented Reality framework](image)

**Figure 2:** Augmented Reality framework. Unity is the game engine that enables Vuforia which is where the AR-technology is running.

The Android app also contains the game engine Unity 3D module which allows the usage of Vuforia, which can be seen in Figure 1 and more detailed in Figure 2. This makes up our Augmented Reality framework. The framework uses data from the user and the database to simulate 3D game elements for the player to view in real time. In order to do this, Unity utilizes the mobile phone’s camera, gyroscope, and accelerometer to get the data to simulate the 3D game elements. The gyroscope and accelerometer are components in mobile phones that work together to calculate how the phone is tilted and moving[14]. Then the data can be used with Vuforia’s AR tools directly inside of Unity. The resulting AR module then is exported to our Android programming environment in order to integrate it with our application.

The Firebase database is structured in JSON files. JSON is an open-standard file format used for transmitting data objects [17]. In JSON you can have the basic data types: Strings, Numbers, Arrays, Booleans and other object literals. This allows constructing the information in a data hierarchy. We have split up our database in three different categories:
6 System Structure

- **Users**
  - The user category contains user information about the player, how many resources they have and how many soldiers they have.

- **Forts**
  - The fort category contains information about where the forts are located on the map, attributes and which player is currently owning it.

- **Resources**
  - The resources category contains information about where the resource is located on the map, the type of resource as well as the value of the resource.

When a user logs in for the first time they create a user, which is sent as a Java object to Firebase. Firebase then takes the object and inserts it into the Users category. When the users perform an action in the game such as picking up resources or buying soldiers the object is updated and the information is sent to Firebase to be updated. Starting the map sends a notification to Firebase that we need information about nearly located Forts and Resources to display on the Map to interact with. When a player interacts with the objects both the User and Fort/Resource category is updated.
7 Research about Gamification and Resulting Game Elements in App

In this project, the idea was to implement elements from games and gamification that were rooted in research. This was done in order to maximize the incentive and motivation created for the players.

The core of the research stems from an article researching gamification in health and fitness apps [19]. In the article, the researchers try to identify general game elements of fitness apps that can be used to measure if the current market of fitness apps follows behavioral theory and recent games research. Six core components of gamification were identified by "reviewing the current body of literature and finding common themes and components of gamification used or discussed in the literature for impacting health behavior". These generalized elements were implemented in our project as according to the report they are the most common. The components were:

- **Leaderboards**: There will be a way for users to see their statistics compared to others. This will serve as both a competitive and social aspect. The rewards and achievements that the user have accumulated will be shown here and ranked in a numerical order against other users.

- **Levels**: Users will be rewarded with experience points, granting them levels as they progress through the game. A level is a way for the users to compare their progress against other players. For example, the leaderboard ranks users according to their level.

- **Digital rewards**: When completing tasks, the users will be rewarded with small digital rewards such as resources and experience. This can then be spent to further purchase rewards. Examples could be items or weapons for the user’s avatar.

- **Real-world prizes**: This element will not be implemented. Since it requires financial investment to reward players with prices in the real-world, it would be a future expansion not within the scope of this project.

- **Competitions**: Our game implements competition between players by having them build and attack forts. Having a fort gives rewards in form of resources and experience points, so competing against other players is encouraged.

- **Social or peer pressure**: Users will indirectly experience social pressure from other elements. The main cause is the competition, which if implemented with social features such as friends and leaderboards will cause pressure.
In the same article, these elements were searched for in an analysis of 132 apps on the Apple app store. This was done to see if the market follows the current industry standards. Furthermore, 13 health behavior constructs were analyzed. These constructs were taken from different models and theories in behavioral science. In our project, we use these constructs to motivate our choices of game elements and associate them with theory. We will not use all 13, instead, the constructs that will be focused on are:

<table>
<thead>
<tr>
<th>Construct</th>
<th>Definition</th>
<th>Example</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer pressure</td>
<td>Using peers to enforce new rules about behaviors or changing social settings/-context to eliminate negative influences on behavior.</td>
<td>Competitions to encourage friends to achieve their goals, such as challenging each other to lose weight.</td>
<td>TTMb,</td>
</tr>
<tr>
<td>Incentivization</td>
<td>Based on operant conditioning, pairing the behavior with rewards or incentives to train an individual to value the behavior</td>
<td>Gaining points that can be cashed in for a monetary prize or creating a self-reward.</td>
<td>TTMb, SCTd</td>
</tr>
<tr>
<td>Goal-setting</td>
<td>Creating small attainable goals to help individuals begin new behaviors and keep commitments.</td>
<td>Setting goals to run 3 times a week for 30 minutes.</td>
<td>SCT, Fogg</td>
</tr>
</tbody>
</table>

TTMb=transtheoretical model  
SCT=social cognitive theory  
Fogg=BJ Fogg model of behavior

Table 1 Behavioural constructs

The theoretical models associated with each construct is identified from different works in behavior science. The TTMb and SCT are both in an article by Doshi et al [8] and the BJ Fogg model is presented in an article by BJ Fogg himself [2]. How these models function in detail is out of the scope of this project since it belongs to advanced behavior theory. However, they will be briefly described.

The transtheoretical model (TTMb) proposes that people transition through several stages in the process of altering their behavior patterns [30]. Social Cognitive Theory (SCT) describes the influence of individual experiences, the actions of others, and environmental factors on individual health behaviors [23]. The BJ Fogg model says that behavior is a product of three factors: motivation, ability, and triggers. For a behavior to happen, these three factors needs to be present at the same time [2].

These three constructs will be present in our game. Peer pressure will be implemented
in our leaderboards. It also ties directly in with the gamification element *Social or peer pressure*. Incentivization will be present in our levels and experience and is also connected to earlier gamification elements. Lastly, goal-setting will be implemented by having the users input their distance goals and then creating quests with them in mind. Thus, our elements will reflect the three models mentioned above and to some degree be rooted in behavioral theory.

8 Requirements and Evaluation Methods

The requirements we have are divided into several different categories. The categories are technical, user experience, gamification, and non-testable requirements. Evaluation methods differ depending on the nature of the specific category. The purpose of the requirements is to be able to measure to what extent the goals set by the project have been fulfilled.

8.1 Technical Evaluation

For this section, the requirements are italicized with the following text describing the method used to evaluate. The following will be evaluated:

- *Functionality of the user interface by testing buttons and everything that the user can interact with*. This will be tested by having testers try all the interface functionality and observing the result. Buttons for building units, navigating between screens and similar parts will be tested. The desired functionality should be reached at least 90% of the time to ensure that the interface does not inhibit the ability to play the game. However, the 1/10 will be allowed to malfunction is provided because of the short timespan of the project. The time required to make it function 100% will be spent elsewhere.

- *Stability of the system*. While using the application it should not crash more than 1/60 times. This will be tested by launching the application 60 times and visit all views and press all buttons while observing the result. To avoid testing the same path every time, we are choosing different paths at random when they are possible. The tested parts of the system will be the initialization of the Android application and database. Also, the stability of the AR module will be tested by launching the AR view. If the system crashes, both the camera or the AR framework could be malfunctioning.
8 Requirements and Evaluation Methods

- **Loading and modifying data from the database.** This requirement will be tested implicitly by us developers testing other requirements, such as launching the application and pressing buttons. If the data read from the database does not display correctly 90% of the time, it is deemed not reliable enough to not detract from the user’s experience as previously.

- **Cross-platform exportability.** The developed AR module should be able to work in both Android and iOS programming environments. This will be tested by loading in the Unity application in both our Android application and an iOS emulated application. This is a requirement for the external stakeholder to be able to use our work in multiple future scenarios, as well as maximize the reach of the project.

- **Evaluation of the functionality of the AR technology.** 3D objects should be rendered in the mobile cameras view with the correct orientation. This will be tested by opening the AR application and move the camera to different positions. The desired functionality is to be able to turn the camera left, right, up, and down with the 3D-model rendering in the same position in relation to the user. Also, the 3D-model should be sensitive towards the user moving forward and backward with the model rendering larger and smaller. If these requirements are fulfilled the user should be able to move around a 3D-model that is stationary in relation to the user.

### 8.2 Testers

The testers for our application are students aged 20-25 studying in a technological field. This is because they are included in our target audience of young individuals between 10-30. We acknowledge that the chosen testers do not cover the whole target audience and do not give a thorough evaluation of how the app works for all types of players. However, it is enough for testing the basic functionality of the app and to expose big flaws early in the development.

Our external stakeholder will also be included as a tester. They will participate in the survey to give feedback on their experience as a general user. As already described, they will also have requirements that the AR module will work with iOS programming environments.
8.3 User Experience

A general evaluation to see how different aspects of the game is perceived by the players. Testers will play the game and then fill out a survey that has questions about their experience with the game. The questions that are not text answers will be on a scale from 1-4 (e.g. very bad, bad, good, very good). We use this scale in order to make the tester say something in the game was either good or bad. All questions are in the appendix. What we evaluate here are two requirements for the game:

- **Movement and motivation for playing the game.** The game has a goal of getting players active. Therefore we want to know what the testers thought about having to move around to play the game. Another question is to ask how many minutes they think they will stay motivated to play the game if they were to play every day. What elements in the game do they find motivating and not motivating.

  It is important to evaluate how well the goal of a motivating game was fulfilled. For the game to pass as successful at motivating players we will look at two parameters. The first parameter is that we want the questions about movement and motivation to get positive answers. This would mean that the game’s idea and concept are approved. The second parameter is that we want the testers to think they would stay motivated for at least 30 minutes a day.

- **Game experience and improvements.** One goal of the game is that it should be fun to play. There are questions on the survey of what the players thought of the game. What was good and what could be improved. What they thought about the gameplay and what the impressions of the UI design were. This is important for improving the game and for sending to our external stakeholder if they want to continue to develop the game.

8.4 Gamification

There is a requirement for the use of gamification research in the game. The gamification elements decided to implement as described in Section 7 are:

- Leaderboards
- Levels
- Digital rewards
- Competitions/challenges
8 Requirements and Evaluation Methods

- Social pressure

The prerequisite is that each of these elements exists in the game. Each of these elements is evaluated individually with us answering the following text questions. We answer these ourselves because we do not require testers to know about gamification elements.

- How does the element affect the gameplay?
- Could the element increase the user’s motivation to play?

With the results of these questions, the degree of gamification implemented in our application can be measured. However, the impact and motivation created for the users by these elements will not be evaluated individually by the questions in the survey. Instead, we will look at text answers and general impressions of the game to draw conclusions of the elements effectiveness.

8.5 Non-testable Requirements

There are requirements that are not possible to test during this project. The time required exceeds the set deadline.

One of the important requirements we have is that the game should give incentive for players to keep playing during an extended period of time. This could be measured by having a set time interval in which testers activity is monitored. There are two important factors to look at here. The first one is to see how individual user activity changes over time. This is to see if the game is successful at motivating players over a longer period of time. The second one is to see if the total amount of users decreases or increases. This is since even though some users stop playing after a short amount of time, the general user base could still increase over time.

It is also difficult for our project to measure long-term health benefits. Therefore, the evaluation of the impact on physical activity will be limited. Instead, the focus will lie measuring the motivation created in the user’s experience. If short-term motivation is present to play the game and physical activity is generated, then theoretically long-term health benefits could be observed.
9 Design and Gameplay

Here we will describe the design of the app and how to use the app. The overall theme of the app is medieval and cartoony which will fit our target audience. The goal of the game is to build the largest army and own as many forts as possible to show to the other players that you are the best on the leaderboard.

9.1 Log-in and Create Account

![Login Screen](image)

**Figure 3: Login Screen**

When the user starts the app for the first time the user is prompted to log in and create an account as can be seen in Figure 3. The only thing the user has to enter except for email and password is a unique username. The username will be displayed to other players in the game.
9.2 Home Screen

After logging in, the user will arrive at the home screen which can be seen in Figure 4. At the top of the home screen, we have an image which is a view of the user’s character. If you click on the profile image you will arrive at the profile screen as can be seen in Figure 5. Further down on the home screen we have four buttons. The top-left takes the user to the map screen, the top-right to the leaderboard and the bottom-right to the army screen. The bottom-left one is for settings which are not implemented.
9.3 Profile

![Profile Screen](image)

Figure 5: Profile Screen

On the profile screen, various information is shown to the user as can be seen in Figure 5. It shows what type of- and how many resources you have on the top right. In the center part, a progress bar can be seen that displays the current level and progress on the current level. In the bottom part of the screen, there are buttons for quests, achievements, army and an inventory. However, the functions for quests, achievements, and inventory are not implemented.
9.4 Map

On the map screen, the user is shown a customized map with the user’s current position as a blue marker as can be seen in Figure 6. On the map, there are also various resources spread around such as wood, stone, and gold. They are represented as icons on the map and can be seen at the top of Figure 7. If the user is close enough on the map to a resource they can press on it and it will be added to their inventory as well as give them experience points. These resources can then be used to purchase soldiers, build forts and upgrade them. As also can be seen in Figure 6 there is a fort. Pressing on the fort will display a pop-up screen that shows the current level of the fort, who owns it, and its current health. If there is no player currently owning the fort the user can choose to build a fort there. If the fort is already taken the user can choose to view the fort in AR or to attack the fort with his army to try and take it for themselves. Owning a fort generates resources for the owner and gives points to show on the leaderboard.
9.5 Army

On the army screen, there are different units that the user can choose to build as can be seen in Figure 7. Pressing on the units icons shows information about them such as damage and health points. On the far right of the screen, you can press the button to build one more unit.
9.6 Social

![Social Screen](image)

Figure 8: Social Screen

On the social screen, there is a leaderboard that displays the best players in the game as can be seen in Figure 8. Users are ranked by their level which in turn is determined by the amount of experience gained.

10 Implementation of AR

The AR module is built in the game engine Unity 3D. To do this, Unity takes assets from the Vuforia framework to augment objects in the view of the camera. The module can then be exported to be used as a standalone application or external library.
10 Implementation of AR

10.1 Rendering 3D Objects into the Real World with Augmented Reality

Unity features a viewport in which objects can be placed to simulate a 3D-environment. Cameras, lights, and objects can all be placed and transformed on an x, y, and z-axis. In our project, a camera was placed and then linked to be used with Vuforia. This means that the augmentation of the objects will be performed from the camera’s view. Then, an object was placed in the camera’s view. To move the object with the camera’s movement, Vuforia was set up to use rotational tracking. This means that data is read from the phone’s gyroscope to track where the object should be in the camera’s view. If turned away from the object, it will not be visible. The viewport also features a grid for simulating the ground upon which the object is placed. This will align the object to ground relative to the elevation of the camera.

![Figure 9: Unity viewport with object in front of camera](image)

The AR framework that we chose only supports marker- or vision-based AR. This means that all data that is used to augment is provided by images. Using this kind of AR, we can’t move objects in relation to geographic location. The other kind of AR that simplifies this is called location- or markerless AR. Since Vuforia does not support this, we will not be able to get closer or move objects when the user’s geographic location moves. With location-based AR, we could provide our location to the framework which would then scale the object depending on how close the camera is.
10.2 3D Models

For this project, we chose to use models from other sources since it would likely require a significant amount of time to learn a 3D modeling software with no prior experience. The models were taken from Sketchfab’s community library. It’s a website where users can share 3D models with each other [25]. They are licensed under the Creative Commons license, which means that you can use the model as long as you credit the author. This was done under a tab in the applications settings.

11 Evaluation Results

11.1 Results of the Technical Evaluation

- Stability. For testing stability and user interface of the app was launched 60 times. We did the following steps each time in random order where they were possible
to check stability. Click on profile. Click on Army. Build one of each unit. Click on the back button. Click on Map. Collect one of each resource. Click on fort. Attack fort. Rebuild fort. Close app. Click on View Fort (AR).

![Stability of different functions in app](image)

**Figure 11:** Different parts of the app tested and their result in percent. The ones named GoName means changing to that screen. BuildUnits and CollectResources are actions within the game. The success rate comes from how often the app responded correctly to the different commands.

The results were good as shown in Figure 11. For the parts that are implemented, the app is stable in most cases. There exists a failure case when building a new fort after attacking it which is not responding correctly. However, the app does not crash but the gameplay is hindered.

- **Database accuracy.** While doing the stability test, the values in the database were observed in order to see if it responded correctly. One example of this is when collecting a resource on the map, the database should show the updated value of the user immediately. The results were that the database works 100% of the time.

- **Evaluation on the functionality of the AR technology.** For the AR technology to be approved, the AR module should be able to render a 3D fort in the correct position as described in Section 8.1. The AR-module was opened in and then turned to the left, right, up, and down. This worked correctly as the 3D-model disappears from
the screen if the camera was turned enough. Next, we tested the sensitivity for moving forward and backward. This did not work at all as the 3D-model did not render bigger or smaller. The AR-module fulfilled one out of two requirements.

Our external stakeholder also tested the AR module and gave some feedback on its functionality. The verdict was that it was interesting and cool, but did not add that much to the overall game. AR is new technology which sparks the user’s attention, but they thought that it needs more integration with the gameplay to be worthwhile.

- **Functionality of the user interface.** This was tested by observing the testers while they played the game. We observed flaws in the design where more information could be displayed on the different screens. One example is the resource cost of building a unit could be printed out directly under the name of the unit. Also, it was difficult to begin playing the game without any instructions. However, after some explanation from us, the testers could play the game smoothly with fewer wrong clicks as they played more.

- **Cross-platform exportability.** It was important that the AR-module was exportable to a framework for iOS in order to reach a broader audience. We tested this by importing the Unity project, which includes the AR engine Vuforia, to a project into Xcode. There we started the AR app in an emulated iOS environment and it successfully launched. The functionality seemed to be the same when some short play-testing was done. This means that our external stakeholder will be able to use the module to develop iOS applications in the future.

### 11.2 Results from Survey

For testing the app we used 6 testers who played the game for about 15 minutes each. After they were done playing they were asked to fill out a survey with questions about the game. We also observed the testers while they were using the app to look for improvements to the UI.

The answers to the survey, shown in Table 2, shows that the project was successful at making a fun and motivating game considering being in an early development stage. However, there are many suggestions for improvement which can be seen in the text answers.

Some of the questions were related to motivating physical activity. The testers answered that they could play the game for an average of 70 minutes per day without getting bored which is more than what we expected. They were also generally okay with having to
### Table 2 Compilation of survey

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What did you think about having to move around in order to play the game?</td>
<td>Average: 3.33/4</td>
</tr>
<tr>
<td>How motivating are the in-game rewards for playing the game?</td>
<td>Average: 2.33/4</td>
</tr>
<tr>
<td>What would you want to add in the game to make you play more?</td>
<td>More progression, levels, quests. More functions with resources</td>
</tr>
<tr>
<td>How long time could you play this game each day without getting bored?</td>
<td>Average: 70 minutes</td>
</tr>
<tr>
<td>How fun did you think the game was?</td>
<td>Average: 2.83/4</td>
</tr>
<tr>
<td>What did you think about the design of menus and map?</td>
<td>Average: 3.16/4</td>
</tr>
<tr>
<td>What would you add or change in the design?</td>
<td>More unified design. More descriptive icons. All buttons should work.</td>
</tr>
</tbody>
</table>

move around in order to play where they gave the average rating 3.33/4. However, they rated the in-game rewards, which are one of the important gamification elements, as 2.33/4 which is interpreted as bad. The text answer that is connected to motivation also says that more progression, levels, and quests are desired within the game. Also, more functions in the game that requires spending of game resources were desired.

The testers rated the game between fun and boring with an average rating of 2.83/4. They suggested improvements similar to the question of what would make them play more and also added some more points. More items and customization for the user’s character and also more social features added like a friends list. More functions and development for the AR module was also suggested, such as interaction with the object. The UI was rated 3.16/4 which is considered good. Criticism was on buttons that have no function, icons are not descriptive enough, and wanting to have a more unified design throughout the app.
11.3 Gamification Results

Gamification elements were evaluated as described in Section 8.4. The prerequisite was that each element should be present in the game, which is fulfilled. How effective individual elements was at motivating players is not measured as mentioned in Section 8.4. This is instead measured overall in the survey where the testers could answer questions about how fun the game was and what they thought about the in-game rewards. They also gave text answers for what they liked or miss in the game. For each element the following questions were answered:

- How does the element affect the gameplay?
- Could the element increase the user’s motivation to play?

**Leaderboards:** The leaderboards affect the gameplay by allowing users to compete with each other. Our implementation ranks users by experience which makes it something the users could desire. This competition for points can possibly create motivation for users. It can also generate social pressure as described in Section 7.

**Levels:** Experience points are implemented and gaining enough will grant users levels. This affects the gameplay by giving the users a sense of progression and a goal to performing tasks. It can create motivation for players by being the main reward for doing any of the actions inside the app.

**Digital rewards:** The users are able to get rewards such as resources and experience. With resources, the users can build units to attack forts, but rewards such as items are not implemented. It affects the gameplay by being the main focus for the users. Resources are required to perform in other parts of the game, such as attacking and defending forts. This means that acquiring resources can be motivational for the user.

**Competitions/challenges:** The gameplay is affected by having users compete for control over forts. Only one user can control a fort at a given time. As it also gives rewards, users can likely get motivation from this element. The leaderboards also indirectly provide competition.

**Social pressure:** Social pressure in the game is found via a combination of elements in like the leaderboard, experience points and the game being multiplayer. These combined create pressure to not fall behind on progress compared to your friends. However, this gamification element would be greatly improved if a friends list or some sort of team play were integrated into the game.
12 Results and Discussion

The resulting game application is deemed to have the necessary functionality and to work as intended. The different parts of the system presented in Section 6 are implemented and able to communicate with each other. The results are divided into subsections where the individual parts are described.

12.1 Interpretation of Technical Evaluation

The analysis of the technical evaluation revealed that the system was stable and we had no crashes in the app. However, we found bugs that must be fixed to further smooth the flow of the game. The database responded very accurately to all inputs and outputs we are currently demanding of it. But these results are still when just one to three players are playing concurrently. For a full-scale game with possibly thousands of players there need to be more evaluation and an added stress test of the database. The interface was found to be working but needs improvement. Most importantly there needs to be more information on a lot of screen views so the user can avoid having to look up things like current resources and army count in their respective tabs. The UI also needs to be updated to be more user-friendly as there were some problems with navigation in the app. Also, the goal of the game and how to play it was confusing. A tutorial on how to navigate and play the game could also help with this.

12.2 Interpretation of Survey Results

When analyzing the results of the survey we found the testers approved the concept of the game. The concept of the game was generally approved because the testers were okay to move around, they approximated to stay motivated to play for 70 min/day, and the UI was rated as good. This shows that the core parts of the game, like physical movement and general gameplay, was approved. It also shows that the game could be successful at motivating players for physical activity which is one important goal of the project.

Gamification elements make up most of the content in the app. The testers said that they could play the game for 70 min/day and rated the game positively on most questions. The text questions revealed that the testers wanted more of the already implemented gamification elements as well as the addition of new ones. From this, we can conclude that the gamification elements in this app increase the user’s motivation to play.
The lower scores of the survey came on the contents of the game. Most criticisms came on the game lacking content like daily quests or more usages for in-game resources. These are elements that could be added later and the survey scores suggest that this is the next area to focus on. Worth to note is that most suggestions for improvements are considered gamification elements which are possible or planned to be added.

In general, the findings of the evaluations gave us important and necessary feedback for continued development. For most parts, the results were according to our expectations considering the early development stage of the game.

12.3 Map and Tracking

The application successfully tracks the user’s position using the Google Maps API and displays it in the game. This requires the application to have permission to use location services. Then the user’s position is represented by a blue dot and will move with to the corresponding map coordinates. The map view is implemented as described in Design and gameplay, with a customized design. Resources spawn randomly around the user and disappear when picked up as well as respawn after a set amount of time. Forts are implemented at fixed locations and can be built, attacked or viewed in AR.

Objects such as resources and forts in the map are only interactable if the user is within a limited distance. The map initially is centered around the user. However, the area that can be zoomed and panned are limited to prevent the user from gathering information from a large area. The map screen is tilted to provide a three-dimensional view and the user can drag with two fingers to change the tilt.

The application is susceptible to faking location by using a GPS spoofing service. This was difficult to prevent and time-consuming, which lead to it still being unsolved. For our purpose of having an application where the user should not be able to fake progress, it is not good. However, in order to do so, the user has to manually go through the whole process of setting up such a service. Most users would hopefully not do this.

Still, the game requires the phones GPS location to change in order to progress. This eliminates sedentary playing granted that the user does not use a GPS spoofing service. This helps us towards achieving our goal of preventing fake progress.
12.4 Augmented Reality Module

The AR module is contained within a Unity application object and is opened when AR needs to be displayed. When launching the AR module there is a time delay. This is due to having to open an instance of the Unity game engine. This is regrettable, but unavoidable unless approaching the problem as described in 12.4. Also, another non-free game engine or AR framework could have been used but might have given the same result.

The game engine renders a game object at a distance from the user in their view. The object is aligned with the ground, but floating, which means that changes in elevation will take the object off the ground. This is a result of not using ground plane detection, which was not used as described in Section 3.1.

12.5 Alternative Techniques and Methods

Right now there is a 10 to 15 second loading time for starting the AR module. This is because the AR module is a stand-alone Android application which needs to be started every time it is used. Compare it with starting the BankID app every time you have to log-in to your bank on your phone. This is to some extent because of loading times required for the game engine, but also because we are using a personal license. For Unity, without a paid license you are required to have a splash screen with their logo. Another way to go would have been to develop the whole app in the framework Unity. This would have greatly reduced loading time for starting the AR-module. However, we are not sure how much development time we would have lost in learning Unity and C#. It could also have resulted in not being able to use Google Maps and Firebase which are well documented.

13 Conclusions

The result of the project is an application that implements game elements and AR to motivate people to become active. The application works for Android, and the AR module can be exported to develop an application for iOS. It contains multiple elements from gamification that proven from evaluations and tests motivate the users. With this incentive to play the game, users have to walk, run, or by some means get to different locations in their vicinity. Their distance is tracked by GPS to prevent sedentary playing and ensure that motivation is converted into physical activity.
This shows that gamification elements rooted in research can successfully motivate users to prevent a sedentary lifestyle. It is possible that if more incentive is created, more activity is generated. However, our evaluation is within a very short timespan and further investigation is needed. There are also many areas where more work could increase users motivation. For example, the Augmented Reality module could be developed much more. Creating an interactable and large-scale AR application would take considerable time and effort but might provide motivation in equal amounts.

## 14 Future Work

In the future, there is a lot of aspects of the app that are possible for future expansion. Here is a list we would like to develop further to make it a completely playable game that could be released:

- **Scalable for anywhere in the world.** For the game to be able to be released, there is a need for scalability so players can play wherever they are in the world. One example of this would be to make all food stores forts and have resources spawn randomly.

- **Develop the AR-module further.** The AR-module is in an early development stage with few functions. There is a broad range of improvements that can be done and many features that could be added to make the game better.

- **Create a game server.** Create a game server that would keep track of everything so that the players do not cheat and create some order for attacks and such.

- **Balancing the game.** Balancing a game means to tweak resources and variables within the game to make it fairer towards the players.

## References


A Survey
GeoFort Survey

Survey for evaluating the mobile game GeoFort used in the project GeoFort: motivational mobile game using Augmented Reality.

1. What did you think about having to move around in order to play the game?
   *Mark only one oval.*

   1 2 3 4

   Very Bad  Very Good

2. How motivating are the in-game rewards for playing the game?
   *Mark only one oval.*

   1 2 3 4

   Very bad  Very good

3. What would you want to add in the game to make you play more?

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

4. How long time could you play this game each day without getting bored? (minutes)

   __________________________________________________________

5. How fun did you think the game was?
   *Mark only one oval.*

   1 2 3 4

   Very boring  Very fun

6. What could make it more fun?

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
7. What did you think about the design of menus and map?  
*Mark only one oval.*

<table>
<thead>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Very nice</th>
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8. What would you add or change in the design?

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