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Towards Augmented Reality as a witness of passing time, Case Helsinki Railway Station

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This thesis focuses on the use of Augmented Reality in touristic and historical contexts. The idea is to see how it is possible to use mobile devices to render old photos of a place over the reality in order to let the user see how a place evolved through the years.

The work doesn’t use three dimensions representations of the places added to the database, since its main purpose is to create an easily usable application at any place over the world. If scanning a place in three dimensions was mandatory, this would increase the amount of work and decrease the usability of the application. Since social medias are taking a big place nowadays, sharing features are taken in account.

This document shows the different steps of the project. First a review of existing literature and projects, as well as existing frameworks for Augmented Reality is exposed. Second, a prototype is designed. As the project is built around a User-Centered Design, data from a survey (more than 20 people) and interviews (5 people who answered the survey) is collected to determine which features are really useful for users. With the requirements and the limitations known, a framework is chosen to develop the prototype. Next comes the implementation of the artifact, with several approaches and tries. Then, an evaluation of the prototype is done with four people (2 interviewed people and 2 other people). Finally, the discussion takes the research and the results of the evaluation into account to determine how the work was useful.

Keywords
Augmented Reality, historical, tourism, photos, superimposition, social media

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Terms and abbreviations

API: Application programming interface

AR: Augmented Reality

DEM: Digital Elevation Models

HMD: Head Mounted Display

IDE: Integrated development environment

IMF: International Monetary Fund

ORB: Oriented FAST and Rotated BRIEF

POI: Point of Interest

SDK: Software Development Kit

SDU: Scaled Distance Unit

SRTM: Shuttle Radar Topography Mission

UEQ: User Experience Questionnaire

VR: Virtual Reality

1 Introduction

The International Monetary Fund (IMF) classifies all economies in the world into two main categories: advanced economies and emerging and developing economies. At the time this thesis is written (i.e. 2019), IMF considers that there is 39 advanced economies (IMF, 2018). In these advanced economies, a predominance of people owns a mobile phone; for most of this majority, their phone is even smart. According to a study by Pew Research Center, up to 95% of South-Koreans possess a smartphone. The rest of the population owns a mobile phone. On the other hand, up to 25% of Canadians don't own any mobile phone at all! Among all data, the study calculated the median and found out that in advanced economies, 76% of people own a smartphone. They also performed this research in emerging economies and the median drops to 45% (Taylor & Silver, 2019).

All these results indicate that smartphone has become an every-day companion in advanced economies and that it will probably also become one in emerging economies. As a result of this growth, smartphones are more and more considered to be used in touristic contexts; developing an historic or touristic experience on a smartphone nowadays makes a lot of sense, especially at the social media era.

Social medias are part of a lot of people's life and this trend also affects tourism. Up to 44% of social medias users admitted that reviews seen on Internet could have a strong impact on their decision for a travel destination. More than a third of people (38%) use city guides applications and historical sites are part of the top 5 things that travellers have the most chance to talk about on social medias (Živković, Gajić, & Brdar, 2014). These impressive figures compel touristic decision-makers to think about social medias in their strategy.

Imagine you are now a tourist and face the following situation: you're visiting a city and arrive at a place where a monument used to exist – sadly it has been destroyed during a war, an earthquake or any other event. Wouldn't it be great to be able to "see" what this building looked like in its environment? Same idea with the expansion of cities, which makes countryside disappear: how was it when only farmers and/or villagers were living at the place you currently are? This thesis will focus on how it is possible to use modern technologies and everyday devices in order to realize how a place has changed or not.

2 Research question and research methodology

2.1 Objectives of the project

This project's objective is to create an application which allows one to superimpose an old photo of a place on its current state through Augmented Reality (AR), so the user can clearly see the differences between the before and the after. If several photos of the same place are available, the user should be able to switch between the images and see the different years displayed (if available). Since sharing information on social media is important nowadays it will fully be part of the work. This means that the users should be able to share pictures and/or information about a location directly from the app to social medias.

This project aims to create a state of the art, find out available frameworks for this kind of application and compare them in order to find the best suited one. It will also require the design and implementation of a prototype. Furthermore, the project must deliver a comparison of frameworks and a motivated choice for one of those. It must also contain a prototype that tries to implement the results of the research (i.e. with one of the frameworks). An evaluation of the functional prototype will be done, which will rely on its functionalities and its user experience.

2.2 Project scope

This thesis' author should develop a mobile application which should be focused on one location mainly: Helsinki's main railway station. Since this building is in the middle of a city, the interesting point is to see how it would be possible to superimpose a photo in an environment full of buildings. In a second phase and if there is enough time to do so, the prototype should also implement a place in Switzerland, in the county of Valais. The place will be defined during this phase. It should provide a way to enable one to superimpose a photo thanks to the landscape (for example the mountains). The use of two different kind of places is important as it shows how the algorithm would work in environments with different constraints. In a city, buildings aren't subject to frequent changes, while nature landscapes are evolving throughout the year (season changes, etc…).

Since social medias are important nowadays, the application must also implement some social content, such as detailed information about a place, discussions between users or even a share link.

Since it would require too much time to implement them in the prototype, the following features are out of the scope:

- Avatar which gives information about the place
- Communication through a discussion between the user and the avatar
- Morphing of photos to show the evolution through the years
- Cross-platform application
- Marker-based Augmented Reality solution

2.3 Research question

How can Augmented Reality help to reconstruct a historical site?

2.4 Research methodology

This research will be performed by using a User-Centered Design (UCD). UCD is a software design methodology which helps developers and designers to create applications according to the users' needs. By looking at what users want, it is possible to get rid of any subjective assumptions about their behaviour, which will make the application more robust when they will use it. Although it is important to listen to users' ideas, it is also important to know when they are going too far in their propositions and not trying to implement all the impossible ones (Lowdermilk, 2013).

In order to use UCD in this project, a survey will be sent to around 20 people. The survey is used to determine users' experiences regarding AR and mobile applications. Based on the survey's audience, 5 people representing different profiles will be interviewed so they can bring propositions for features. The interviews will be semi-structured since this kind of interviews is perfect when a developer must understand user goals or to gather information about a task flow (Wilson, 2013). At the end of the research, 2 of these people and 2 new will have to test the prototype and provide a feedback through another semi-structured interview. This final stage allows one to assess that the prototype implements desired features and to provide a usability evaluation.

3 Related researches

3.1 Virtual Reality

Oxford Dictionaries defines Virtual Reality (VR) as “The computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors.” (Oxford Dictionaries, 2019b). VR is a full experience of a virtual world and is tricking the human brain to convince the user that he is in another location. From the definition given above, it is possible to find out that VR needs:

- Stereoscopic display to simulate 3D depth
- motion tracking sensors to know how the display should be updated
- input devices to interact with the application
- software to interface devices and applications

These 4 items are mandatory for a fully immersive experience of VR (Tony, 2015). VR can be used in many different fields; Figure 1 shows how AR may help for surgery training.

Figure 1 Surgery training through VR (Time, 2018)

3.2 What is Augmented Reality?

As stated by Oxford Dictionaries (Oxford Dictionaries, 2019a), Augmented Reality (AR) is “A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.”. Other sources also talk about enhanced version of reality and enhancing one’s perception of reality (Reality Technologies, 2019) or even about overlaying virtual objects over the real-world environment (Tokareva, 2018). Furthermore, Ronald Azuma asserts that any system that has the following characteristics can be considered as AR (Azuma, 1997):

- Combines real and virtual
- Is interactive in real time
- Is registered in three dimensions.

In other words, AR is a technology which allows to create new perspective of the real world, by adding more information to it. In order to do so a representation of virtual characters, animals or other objects can be displayed in the world seen by everyone. A well-known example of this technology is the videogame for smartphones “Pokémon Go!”. The users can see small creatures (“Pokémon”) in the real-life environment through their device. With this game’s example, the digital added information clearly appears as part of the real-world from the user’s perspective (Höllerer & Schmalstieg, 2016).

Figure 2 In-game screenshot of Pokémon Go! (Beth, 2016)

To summarize, AR differs from VR by not creating a whole new universe in which the user operates. However, AR consists of adding useful digital content over the reality.

3.3 Brief history of AR

AR and VR are linked technologies through history. A lot of innovations of the past decades can both be considered as VR and AR. In this respect, VR has developed slowly from the 1960s. First in 1962 Morton Heilig created the Sensorama, a machine which was simulating sounds, smells, visions. Then, in 1968, Ivan Sutherland and his student build the first implementation of an AR and VR system called The Sword of Damocles. The users could see digital objects through a Head Mounted Display (HMD).

The first mention of Augmented Reality happens in 1992. Two R&D engineers of Boeing were working on a way to make the manufacturing processes easier: they ended up with a software that could overlay the position of cables so the builders knew where they should put them. In 1997, Ronald Azuma writes an article that will lay the bases of AR, by giving a definition to the technology. Two years later, ARToolKit is released as an opensource project by Hirokazu Kato. ARToolKit is a framework designed to create AR applications, providing combination of virtual objects with real world, 3D graphics, etc… Only one year after, ARQuake is created. It is an AR version of the video game Quake (Figure 3).

AR then continued to develop. It has been quite a while since this technology exist but its applications are increasing as the computers can handle more information while they also get smaller. (Padzensky, 2014; Rampolla & Kipper, 2012)

Figure 3 ARQuake - User's Heads Up Display (Thomas et al., 2000)

3.4 Types of AR

In this section, this thesis' author is going through the main existing types of triggering AR technologies. Some other techniques about non-triggering AR exist, but they are not relevant in the scope of this thesis since they do not react to a specific scene.

3.4.1 Marker-based

Also known as pattern-based (Rampolla & Kipper, 2012), this method needs a marker to activate the augmentation. A marker can have several shapes: a QR code printed on a piece of paper or even real-life objects (Edwards-Stewart, Hoyt, & Reger, 2016). The Figure 4 shows how an application can detect a code from a piece of paper and then display a 3D model corresponding to some plans.

Figure 4 QR code triggering a 3D model (Gorissen, 2013)

3.4.2 Dynamic Augmentation

Dynamic augmentation consists of a recognition of a body or a part of it, like face or hands and then a composition with digital elements. It is also possible for a user to interact with 3D objects with natural gestures like picking up an object with its hand (Rampolla & Kipper, 2012). It is also possible to track a user and fit digital objects on him, such as clothes, in order to be able to try them virtually (Edwards-Stewart et al., 2016). This technique gives an interaction between the user and the AR. Snapchat or Instagram use it in their stories feature: they allow to add objects or filters over one's face (Rousseau, 2017). Figure 5 shows someone's face while Figure 6 shows how Dynamic Augmentation can modify it in real time.

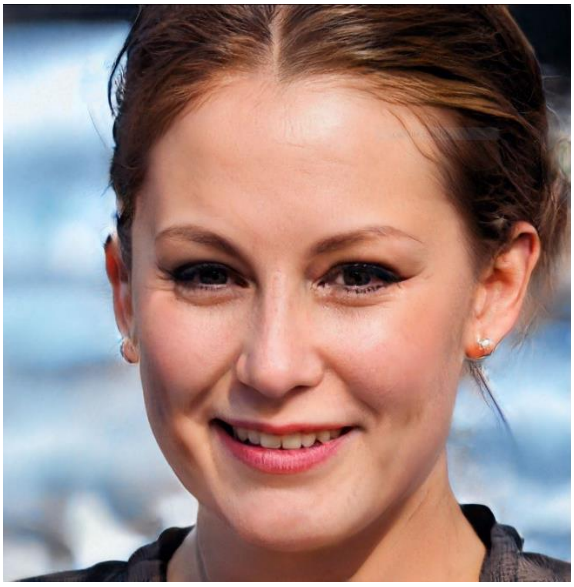

Figure 5 A generated face from the service This Person Does not exist (This Person Does Not Exist, 2019)

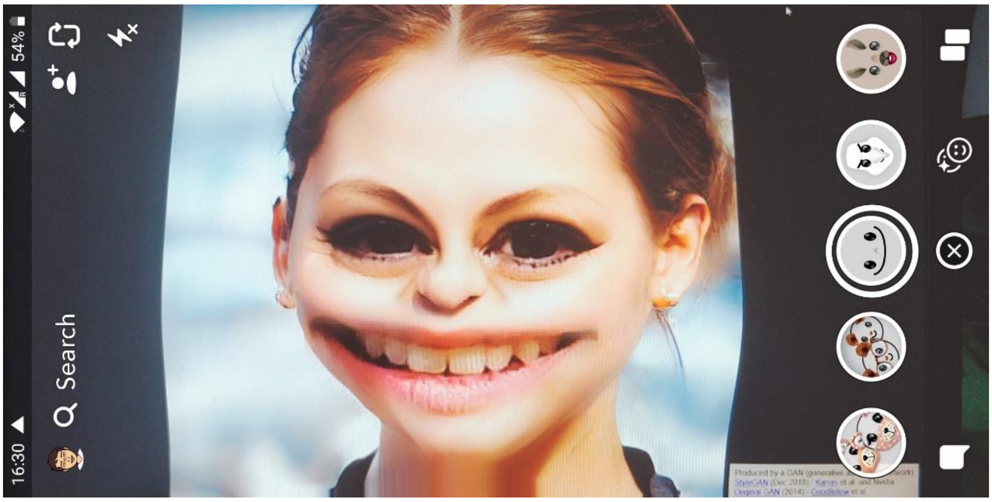

Figure 6 Applying social media filters on the photo

3.4.3 Location

With Location-based AR, the main point is to get the exact location of the device. Usually this step is performed thanks to the device's GPS but also from other triangulation sources. This information and the device's orientation allow to precisely superimpose digital content, such as icons or virtual objects, on the real world (Rampolla & Kipper, 2012). The Figure 7 is an advertisement for an AR flash mob in Amsterdam.

Figure 7 Location triggering AR Content (sndrv, 2010)

3.4.4 Complex augmentation

This type is a combination of all the other types (marker-based, dynamic augmentation and location). The best example for this kind is Google Glass with which users could see relevant information about objects in their surroundings according to their location (Edwards-Stewart et al., 2016). The Figure 8 shows how smart glasses can augment a worker's reality by adding valuable information such as location in the building, number of pieces in stock, etc…

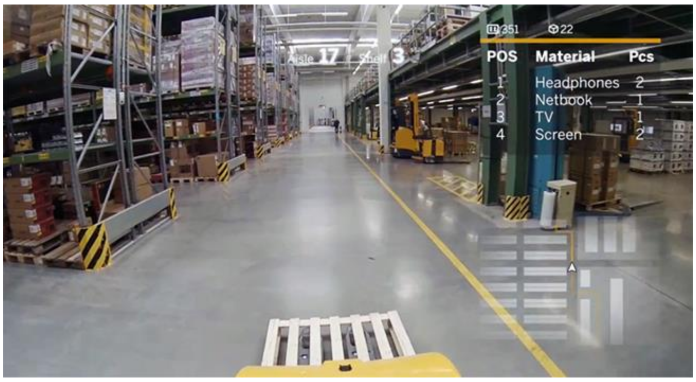

Figure 8 Smart glasses prototype by Wikitude (Wikitude, 2014)

3.5 Existing studies

There are many studies on the field of apply AR to tourism and history. Usually, smartphones are considered as the solution to use. They have wireless connection, have low weight (Kysela & Štorková, 2015) and as seen in the introduction of this thesis, they are widely used. Smartphones also offer plenty of sensors which will be really useful when it comes to dealing with AR. Kysela & Štorková (2015, p. 927,928) cite some sensors like:

- Camera: to capture what’s in front of the user
- GPS Location: to find an accurate location of the phone’s location
- Gyroscope and accelerometer: to determine the directional orientation of the phone

In addition, another study used a set of 4 information for each place they have in their database. GPS coordinates (latitude and longitude), compass direction, historical photos and additional information were the core of the application (Chen, 2014). On top of that, this study’s goal was to find an easy way of developing a generic application for AR and historical photos. The study cited an application developed for Paris (France), *Paris Then and Now Guide*, which was only developed for Paris. Chen explains that the application would work exactly the same in a new city, provided that the database contains data for another city (2014, p. 985).

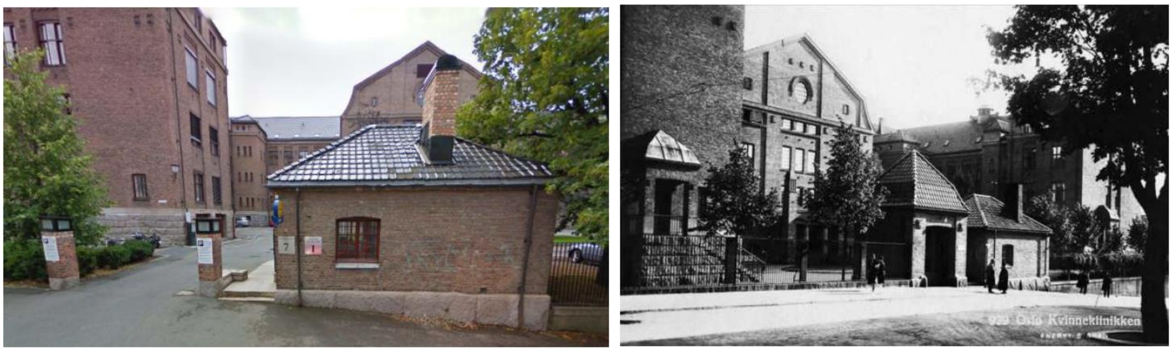

Figure 9 (a) view of Pilestredet Park 7; (b) historical image from 1930. (Chen, 2014)

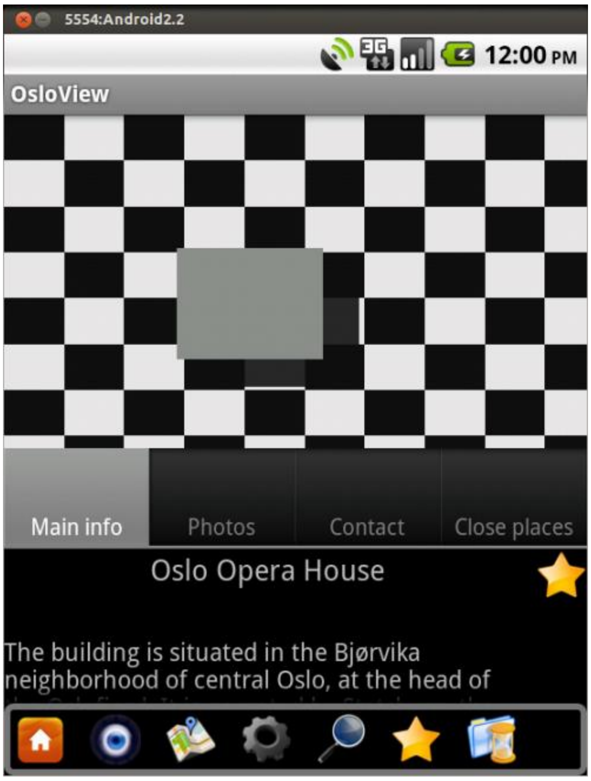

Figure 10 user interface augmented reality view (Chen, 2014)

However, Chen's study doesn't display a superimposition of a photo on the real world. Figure 9 and Figure 10 also show it: you can see the real world on the *Main info* tab and then see historical photos on the *Photos* tab.

Following the ideas of the last research, there is also the Chicago 0,0 app which has to be mentioned. Thanks to a different approach, this research corresponds in a lot of way to the idea looked for through this thesis. The app developed uses two different cameras: the mobile phone's one (hardware) and a virtual one, which relies on the smartphone's sensors, such as gyroscope and compass. The combination of both cameras allows to display content even if there is no tracking point anymore. Supposing that some tracking points have been set through the hardware camera, but the user suddenly moves the phone in such a way that the tracking points are out of sight, the sensors camera can help to know in which direction and range the device moved. By doing so it is possible to estimate where the image should be even if the tracking is not working anymore (Cavallo, Rhodes, & Forbes, 2016).

Figure 11 Half sunken ship in Chicago aligned with reality (Cavallo et al., 2016)

Furthermore, this thesis' prototype could have to deal with environment recognition for example in the case of places located in the middle of nature. In these situations, there might be only a few buildings (or even none), which we could use to snap the photos to. However, the landscape could be used as a help to snap elements. There are some mobile applications which use this kind of techniques, especially when it comes to recognize mountains. One of them is PeakFinder AR: it is both an iPhone and Android application. This application's creator explains that he is mainly using OpenStreetMap and the digital elevation model of the Shuttle Radar Topography Mission (SRTM) project (Soldati, 2019). PeakLens is another app which will perform the exact same task, i.e. identify mountains in the user's field of view. Even if the project claims to be different from its competitors because of its artificial intelligence, it clearly stays on the project's website that it is using SRTM too. (PeakLens, 2019). Both projects work quite well but the code is proprietary, and some people tried to implement the same kind of idea in the open-source world. Horizonator! is one of these projects, which is also using SRTM to generate a skyline of what the user should see in front of him (Kogan, 2019). The thesis' writer will be able to look at those projects if he ever needs to "recognize" landscapes.

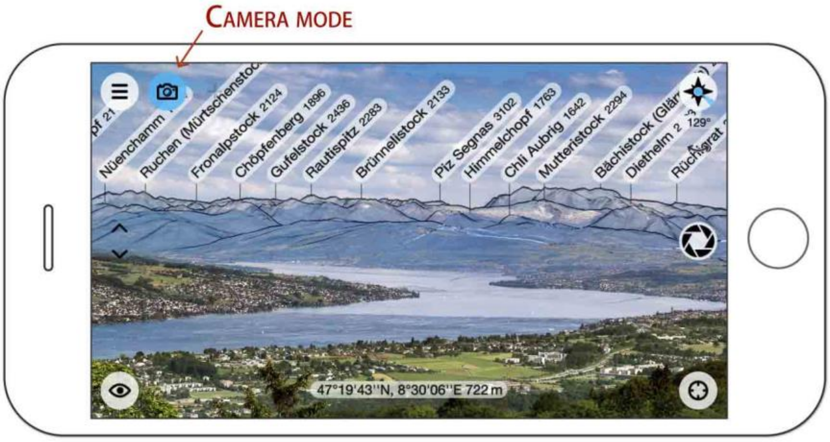

Figure 12 Camera Mode of PeakFinder AR (Soldati, 2019)

3.6 Existing frameworks

A preselection through the existing frameworks has been performed. Some of them seemed to be interesting, such as Metaio. Unfortunately, this SDK isn’t available anymore, since Apple bought the company in 2015 (Miller & Constine, 2015). ARToolKit can also be cited, but again the company behind the SDK has been acquired by DAQRI, also in 2015 (Frederic, 2015). Even if ARToolKit was open source, it is nowadays difficult to find updated versions. ARToolKitX, which was founded on ARToolKit’s ashes, offers an updated version of ARToolKit.(artoolkitX, 2019). The support for this framework doesn’t seem to be really huge, as the forum used by the community is flooded by spam messages (March 2019).

3.6.1 Wikitude

Wikitude is a company which provides an AR Software Development Kit (SDK). The SDK provides the possibility to develop a cross-platform application (iOS, android, Windows). They currently (March 2019) offer a free SDK and other plans, based on a one-time fee or on a subscription, which adds cloud recognition and other features.

Figure 13 Wikitude's logo (Wikitude, 2019)

Wikitude AR SDK allows to use among many features Object and Scene Recognition, Location-Based AR and Instant Tracking-Based AR. The SDK is compatible with many platforms, such as native iOS, Android and Windows, Unity, Xamarin or even React Native (Wikitude, 2019b).

3.6.2 ARKit

ARKit is Apple’s framework for AR applications on iOS only. ARKit only works on iPhones after the 6s version and on iPad pro and iPad 9.7 inch of 2017 (McGarry, 2018). It provides 2D image tracking, a 3D object detection, shared AR experiences and even persistent AR Experiences (Apple, 2019). ARKit was released with iOS 11 (fall 2017) (Apple, 2017).

Figure 14 ARKit logo (Apple, 2019)

3.6.3 ARCore

ARCore is Google's framework to create AR applications. It allows to create applications for both iOS and Android. The main features given by ARCore are Motion Tracking, Environmental Understanding and Light estimation (Google, 2019a). However, not all devices fully support ARCore. The official compatible list of devices is available on ARCore website, but the list is growing (Google, 2019b).

Figure 15 ARCore logo (Google, 2018)

It is also possible to use ARCore with Unity and Unreal Engine. Only some of the Application programming interfaces (API) are available for both iOS and Android (Google, 2019a) ARCore was released in spring 2018 (Google, 2018).

3.6.4 Vuforia Engine

Vuforia Engine is a SDK provided by PTC, an American company. It allows one to recognize models (3D elements), image targets, markers and so on. Vuforia Engine is compatible with Unity. However, the SDK doesn't seem to provide any geolocation features.

Figure 16 Vuforia engine logo (Vuforia, 2019)

Vuforia is free during development time and when the application will be deployed, it will be possible to pay for a one-time license or choose a cloud plan, which then offers updates (March 2019).

3.6.5 EasyAR

EasyAR SDK is a Chinese SDK, developed by VisionStar Information Technology, a company based in Shanghai. It provides native APIs for both iOS and Android. It is also compatible with Unity. The paying license key offers 3D Object Tracking, SLAM, multitype of target detection and screen recording (EasyAR, 2019).

Figure 17 Easy AR logo (EasyAR, 2019)

3.6.6 Kudan

Kudan is a Japanese company which provides Kudan AR SDK. This SDK offers native solutions (both iOS and Android) but also a Unity plugin in order to develop cross-platform applications. It is possible to create both marker and marker less applications and the SDK enables one to use SLAM inside the application.

Figure 18 Kudan logo (Kudan, 2019)

It is free to develop an application with Kudan AR SDK, provided the company has a maximum revenue of 1 million $ per year. When it comes to production, the AR Indie license is free, but a watermark is present. The AR Business license permits to remove this watermark for 1500$ per year. In the end there is also the AR Enterprise license, which price isn't public and allows to have unlimited free support and aims companies with a revenue higher than 1 million $ per year (Kudan, 2019).

4 Design a prototype

4.1 Choice of the framework

4.1.1 Explanation

To be able to compare these different SDK, the thesis' writer defined the features that the SDK should provide and ranked them in three weight: the most important features have a weight of 3, the secondary features have a weight of 2 and the less important features for this thesis have a weight of 1. Each SDK is evaluated through a notation of each feature:

- 2 means that the SDK completely fulfil the requirement
- 1 means that the SDK fulfil it partially
- 0 means that the SDK doesn't match the required feature.

The features are defined below:

- GPS: The SDK should provide a location-based feature, as the timing for this thesis is quite short. It would be possible to use native tools, but this take more time.
- Tracking: The tracking of objects should be available, as the user will probably move the device
- SLAM: As the image will overlay over the real world without a lot of upstream preparation, SLAM is important.
- Support: It is always nice to have some help in case of issues, so the community and the company also have an impact
- Cross-platform: Although it is out of the scope, this thesis should keep in mind that the prototype could maybe be used on different devices, which means that cross-platform could help to decide between two frameworks. However, the impact is small, so the weight is low.
- Price: Most of the SDK have a free version to develop with, but in case it should ever be implemented further away, the price should also be taken in account.

After having graded all the SDK, a simple calculation allows to see which one corresponds the most to the requirements.

4.1.2 Table for comparison

Table 1 Framework comparison

Framework	Info	GPS	Tracking	SLAM	Company support	Community help	Cross-platform	Price	Total
	Weight	3	3	3	2	2	1	1	30
Wikitude		Yes	Yes	Yes	Yes (depends on the plan)	Yes	Yes	Free and paying plans	27
		2	2	2	1	2	2	1	
ARKit		Yes	Yes	Yes	No	Yes	No	Free (account Apple Dev required)	23
		2	2	2	0	2	0	1	
ARCore		Yes	Yes	Yes	No	Yes	Yes (not everything)	Free	25
		2	2	2	0	2	1	2	
Vuforia		No	Yes	Yes	Yes (depends on the plan)	Yes	Yes	Free and paid plans	21

	0	2	2	1	2	2	1	
EasyAR	No	Yes	Yes (de-pends on the plan)	No	Yes	Yes	Free and paying plans	15
	0	2	1	0	2	2	1	
Kudan	No	Yes	Yes	Yes (depends on the plan)	Yes	Yes	Free and paying plans	21
	0	2	2	1	2	2	1	

4.2 Framework choice

As stated in the table, the most relevant choice for this thesis is to work with Wikitude.

4.3 Survey

As this thesis is performed by following a UCD (see chapter 2.4), a survey has been designed. The survey had to be quickly filled in by users and shouldn't ask too detailed questions, as an interview would eventually be done with some of the people who answered the survey. The detailed results of the survey can be found in Appendix 1. Survey results.

35 people received the survey and 28 people answered to it. Of all the people who answered the survey, 14 people were women (50%). The people were from 19 to 29 years old, but most of them were between 20 and 25. Only one person mentioned not knowing anything about AR, which means that more than 96% of the people knew this technology. Moreover, 9 people (32%) had never used AR in their life. The other 19 (68%) mainly used this technology in social medias, video games or for cultural purposes. Finally, only one person (4%) claimed having no interest in such an application, because they wouldn't "spontaneously open the app to observe the evolution of a building". On the other hand, the 27 other people (96%) could tell some features they would like to have in this app. Most of the cited features were:

- Get more information about a building/site
- Find out if other similar places exist around
- See different pictures of the same building/site, to see the evolution
- Take pictures with the overlaid picture
- Share information with other people
- Allow people to add details about a building/site (or even photos)

It is possible to see that the things that stand out from the rest are first getting information in different ways and second share information with others. The prototype should then also take these facts into account.

4.4 Interviews

The surveys were the first part of the UCD process. Out of the people who responded to the survey five were interviewed. By doing so, it was possible to make sure that the direction given by the survey was the correct one. The transcription of the interviews can be found in Appendix 2. Interviews. The choice of the people to interview has been done according to the answers given to the survey and to their profile, which is described in **Erreur ! Source du renvoi introuvable.**.

Table 2 Interviewed people's profiles

Users	Expertise level	Gender	AR Experience	Interest for app
User 1	Advanced	Male	Social Media Video games	Great
User 2	Novice	Female	None	None
User 3	Advanced	Male	Social Media Video games School projects Cultural events 3D viewers	Great
User 4	Novice	Male	None	Minor
User 5	Novice	Male	Social medias Video games 3D viewers Utilities	Great

The first person gave interesting ideas about getting information on a location, while the second claimed having no interest at all in such an application. Then the third person brought the idea of similar places which could be suggested to the user. The fourth person had actually never used any kind of AR by themselves, which was interesting to know more about the representation he had of AR. He was confused between AR and VR, so the discussion helped him to understand the differences and he could bring some propositions too. Finally, the fifth person to be interviewed corresponded to the standard profile of people who answered to the survey, i.e. 21 years old, already used a lot of AR and interested by the application.

The interviewed people were interested in three features: the superimposition, being able to get more information about a location and sharing aspect. Indeed, they seemed to have different interests but all of them didn’t want to only have the superimposition feature. Not only did they want to learn things if they are tourists but also showing what they could see to their friends or family. The sharing ideas mainly came from people younger than 25; older than that didn’t really see the point of this kind of feature but the seeking for more information was more or less equally cited among the people (both surveys and interviews). As it is the user’s requirements and this thesis follows a UCD pattern, the prototype should investigate these directions. However, the writer of the thesis prioritizes the features like below, because most of the users cited the two first features and a smaller proportion wanted the third one:

1. Superimposition of photo
2. Get information about a location
3. Share aspects

4.5 Design overview

The prototype will be focused on the three points defined above. Those points are represented in the UML Use Cases Diagram (Figure 19).

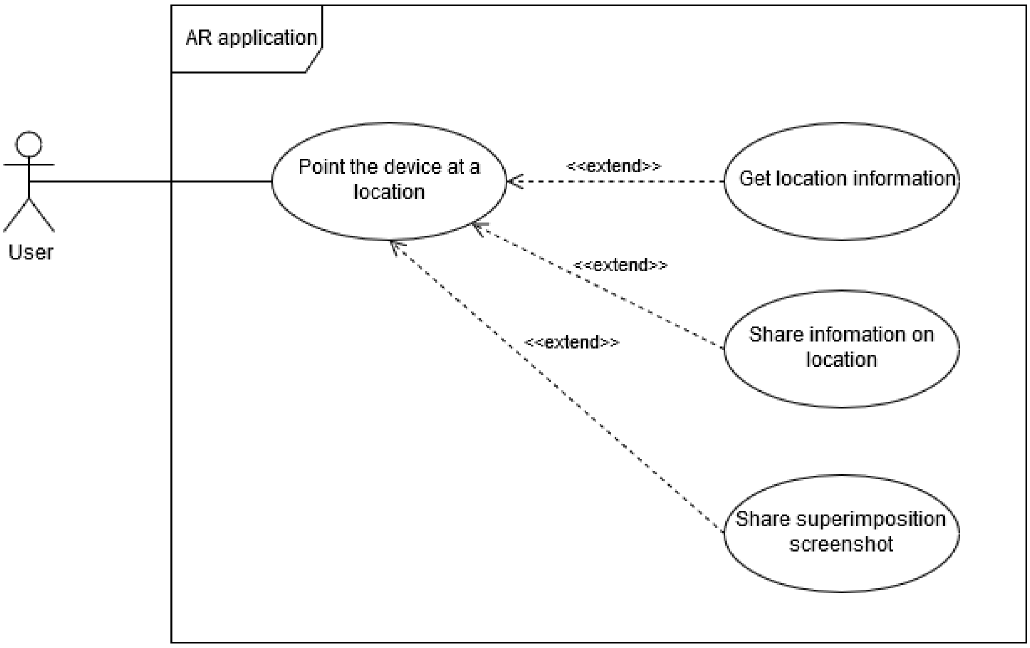

Figure 19 UML Use Cases

The following images reflects some mock-ups for the prototype. The Figure 20 represents the home page of the application, after the user has been located and that the superimposition worked (in case the location has superimposition to offer). The main page should offer several options: first it should allow to choose a year for a picture (if many are available), second it should provide the possibility to get more information (Figure 21), to take a picture (Figure 23) and to share (Figure 22).

Figure 20 Home page with superimposition

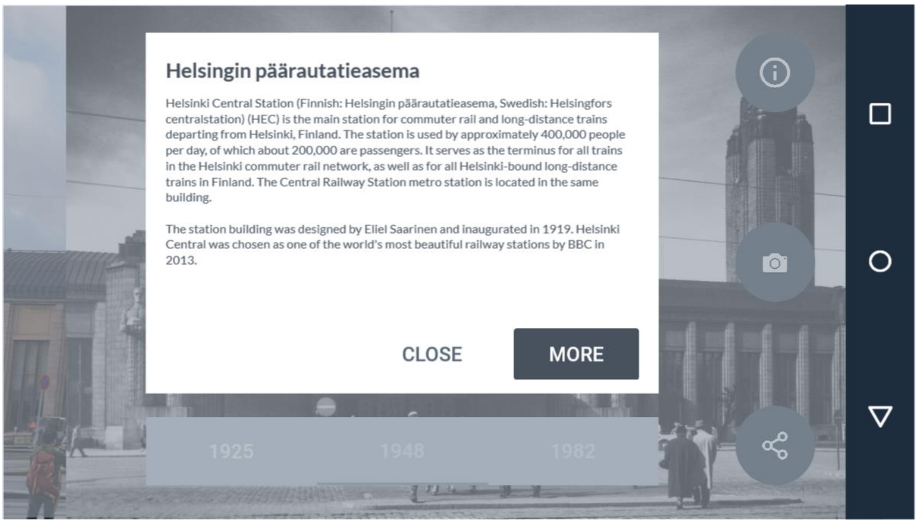

Figure 21 More information about a place

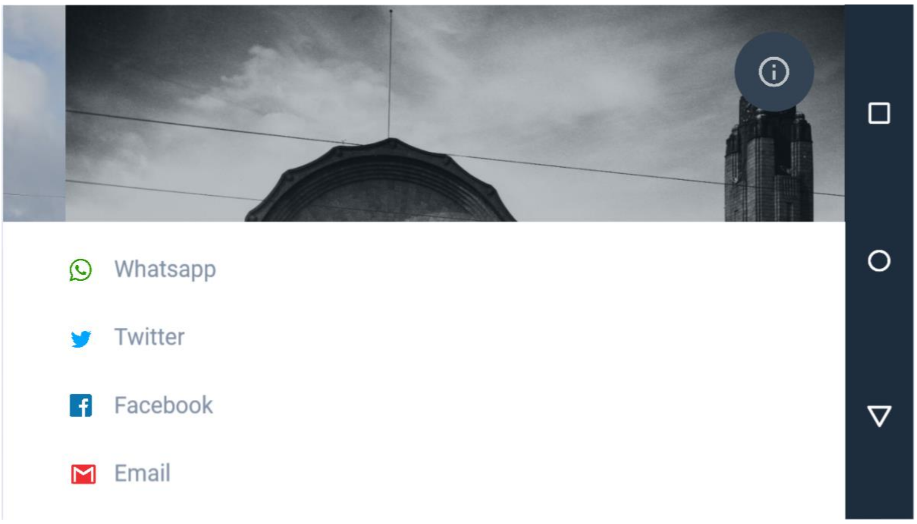

Figure 22 Share data

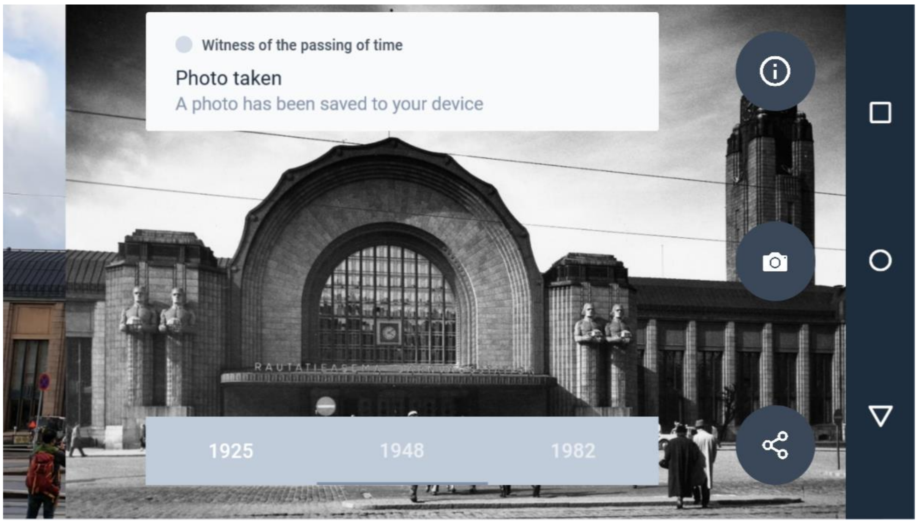

Figure 23 Take a photo

5 Prototype implementation

When the user starts the application, it will automatically trigger the location of the device. When this is done, the app should then retrieve in the database the default picture of the location and superimpose it on the reality. After this first phase, the user can ask for more information about the current location. This should also be retrieved from the database. If several years are available, the user can change the year and then the process is the same: retrieving a picture in the database and superimpose it on the reality. The user may eventually share information on social media directly from the app. This scenario is described by the sequence diagram below (Figure 24).

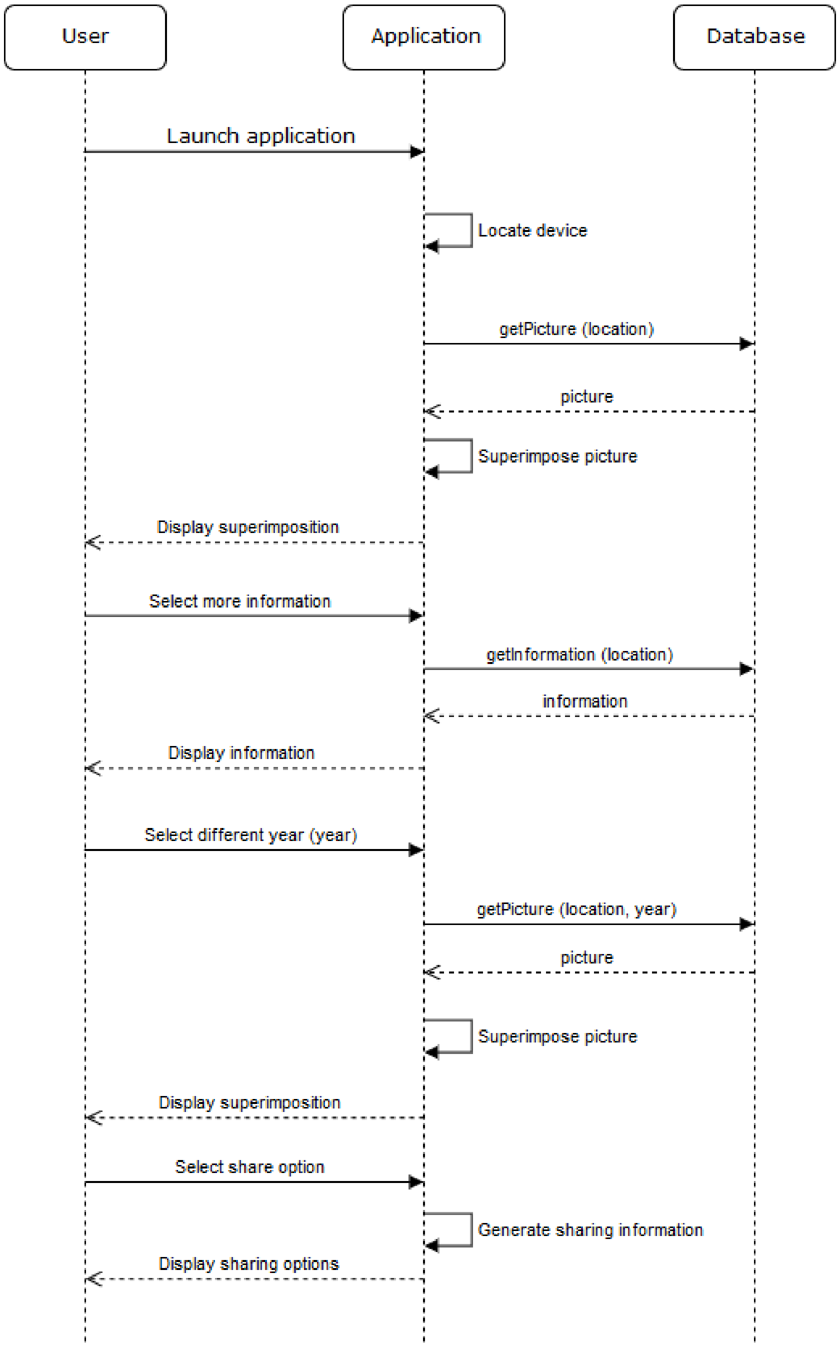

Figure 24 Sequence Diagram

The database of the prototype will be local, as it will only contain one or two locations and that creating a server with a backend is out of the scope of the thesis. This approach can also help tourists to avoid some potential roaming fees. However, as soon as the database is working locally, it wouldn't be that difficult to modify it and perform calls to an external API.

5.1 Development environment

The prototype will be implemented on Android. Knowing this, the Integrated development environment (IDE) used in this project is Android Studio and the main development language used is Java.

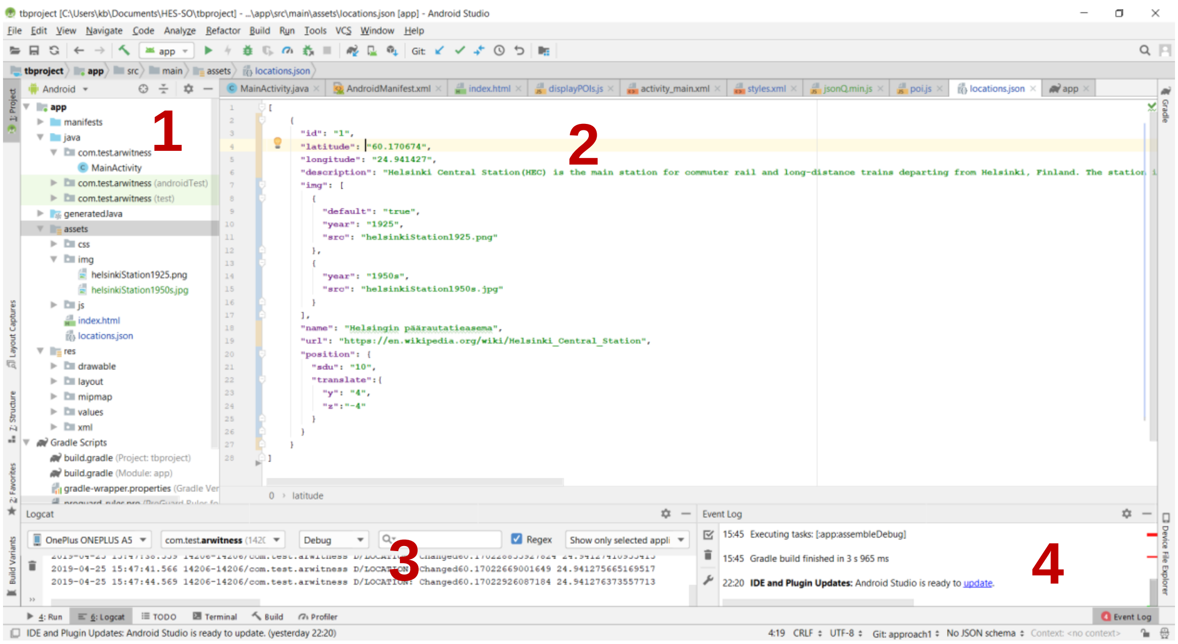

Figure 25 Android Studio

Figure 25 shows Android Studio's user interface. The numbers in the image are explained below:

1. The project's structure. All the files are present in this part of the screen. It is possible to switch the kind of view from Android style to other styles, such as Java project. However, the files will remain the same. When the user double clicks on a file, the file opens in the 2nd part of the screen.

2. Where a file can be edited. Nothing more than this.

3. The log screen. When the application is running on a device, all the logs are displayed in this part. The several tabs allow to see other useful information – such as

TODOs. There is also a terminal in case some actions must be performed in the project's folder.

4. The event log of the IDE. Each time an action is performed by the IDE (building an application for example), the information will appear there.

Wikitude has several different SDKs. The first one to be used in this thesis is the JavaScript SDK for Android. The main advantage of this version is that the geolocation is provided by default. The prototype will then be developed as a Java application, which will be using some JavaScript features, through Wikitude's SDK. All the files needed by the SDK are in the assets folder of the project, while all the others folder follow the usual scheme of Android's applications.

5.2 First approach

Since no image recognition process should be used, the first way is to use the Point of Interest (POI) feature of Wikitude's SDK. The POI feature allows to render an image at a specific location. It is easier to use json files with JavaScript implementation, so this is the reason the first approach uses a file named *locations.json* (Figure 26). This file contains all the relevant data for the application, i.e. the coordinates (latitude and longitude) of the POI, its name and description, the name of the image to be rendered and the webpage where the user will land when they click on "More".

```
[
  {
    "id":"1",
    "latitude":"60.170674",
    "longitude":"24.941427",
    "description":"Helsinki Central Station(HEC) is the main station for commuter rail and long-distance
    "img":"helsinkiStation1925.png",
    "name":"Helsingin päärautatieasema",
    "url": "https://en.wikipedia.org/wiki/Helsinki_Central_Station"
  }
]
```

Figure 26 First version of locations.json file

The workflow of this app is quite simple and follows the first part of the sequence diagram:

- The device is being located through GPS
- When the device has been located, create the POI in the good position
- Link an image to the POI
- Populate the more information modal

The first tests were not satisfactory. Indeed, the POI rendering is really dependant on the quality of the location provided by the device: sometimes it is accurate (Figure 28) and sometimes not (Figure 27). For example, the image was misplaced with an error of around 40 meters to the south-west on Figure 27. Moreover, when the location is correct, the scale of the image isn't. It means that even if the image is more or less placed on the good position, the image does not match the reality at all (Figure 28).

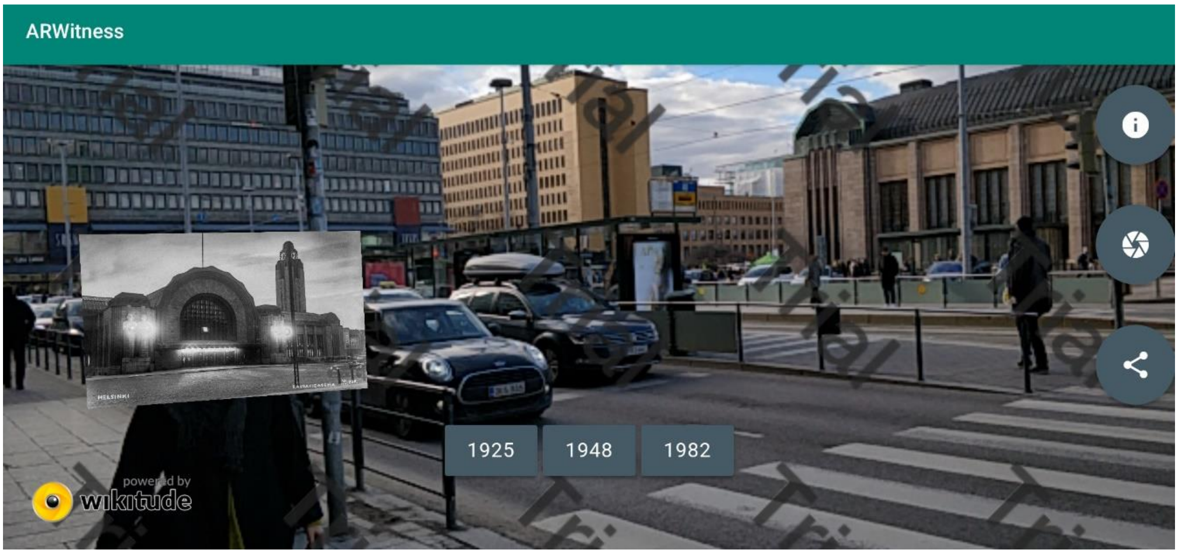

Figure 27 JavaScript SDK - Inaccurate location

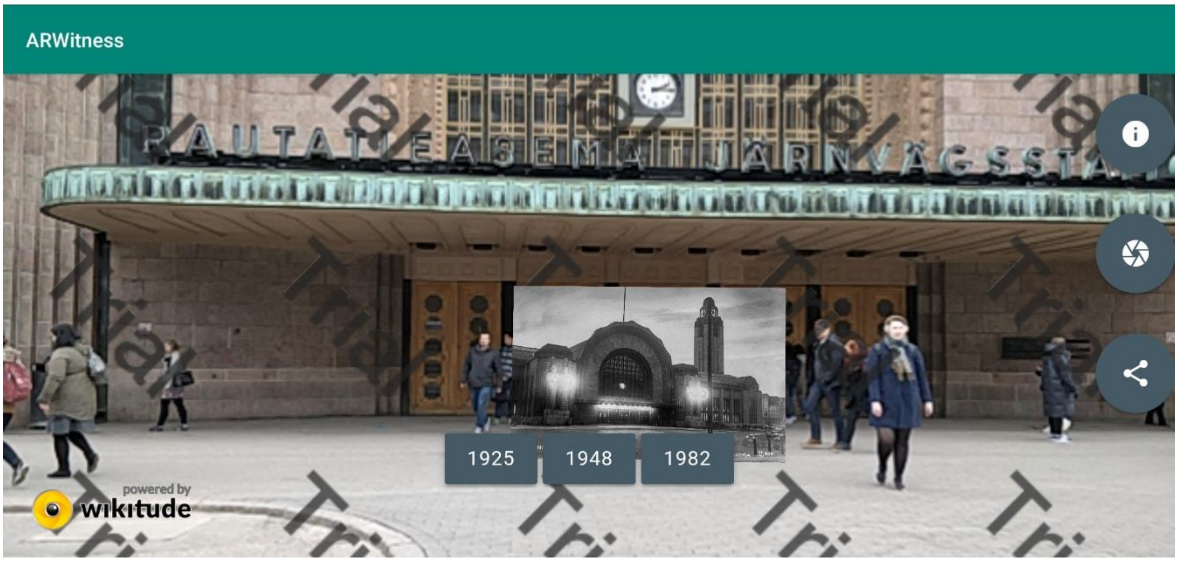

Figure 28 JavaScript SDK - Accurate location

On both Figure 27 and Figure 28, the scale of the station is incorrect. Wikitude has a built-in feature for GeoObjects named Scaled Distance Units (SDU). The documentation explains that 1 SDU correspond to an object of one meter high at a distance of 10 meters. If you set 3 SDU, the object will render at a distance of 10 meters with a height of 3 meters. By tweaking manually, the SDU of each image, it is possible to find a really close overlay, provided that the user is at the good position and the device gets good location information. Figure 29 shows what happens when the location information given by the device aren't correct. On the other hand, Figure 30 renders better result of a superimposition. In that case, both the location and the user's position are correct.

Figure 29 Superimposition issues

Figure 30 Superimposition working well

The file *locations.json* had to be modified a little bit to deal with SDUs and different images of a same location: its last version is visible in Figure 31.

```
[
    {
      "id": "1",
      "latitude": "60.170674",
      "longitude": "24.941427",
      "description": "Helsinki Central Station(HEC) is the main station for commuter
      "img": [
        {
          "default": "true",
          "year": "1925",
          "src": "helsinkiStation1925.png"
        },
        {
          "year": "1950s",
          "src": "helsinkiStation1950s.jpg"
        }
      ],
      "name": "Helsingin päärautatieasema",
      "url": "https://en.wikipedia.org/wiki/Helsinki_Central_Station",
      "position": {
        "sdu": "10",
        "translate":{
          "y": "4",
          "z":"-4"
        }
      }
    }
]
```

Figure 31 Updated locations.json file

As it is visible above, the superimposition does not always fit at the perfect spot. In order to correct this fact, a small feature has been added to the prototype. After the image has been loaded and superimposed, the user can move, scale and rotate it. Using Wikitude's gestures, it is quite fast to implement this feature. When the image gets displayed, a message is provided to the user, explaining him that the image can be moved to another position.

As pointed out by the interviews, sharing information to social medias is important. The sharing process follows these steps:

- The user presses the share button
- A capture of the augmented image is saved on the phone
- This capture is sent via an Intent
- The user chooses which application is going to share the data

It is in the last step of this process that the image and a text are added to the intent for the sharing purposes. The code below gets the image saved, add it as an extra to the intent, then adds another extra containing a text with specific values such as name, year and link before starting the sharing activity.

```
if (contentUri != null) {
    Intent shareIntent = new Intent();
    shareIntent.setAction(Intent.ACTION_SEND);
    shareIntent.addFlags(Intent.FLAG_GRANT_READ_URI_PERMISSION);
    shareIntent.setDataAndType(contentUri, getContentResolver().getType(conten-
tUri));
    shareIntent.putExtra(Intent.EXTRA_STREAM, contentUri);
    shareIntent.putExtra(Intent.EXTRA_TEXT, MainActiv-
ity.this.getString(R.string.share_text, name, year, url));
    shareIntent.setType("image/jpg");
    startActivity(Intent.createChooser(shareIntent, "Share"));
}
```

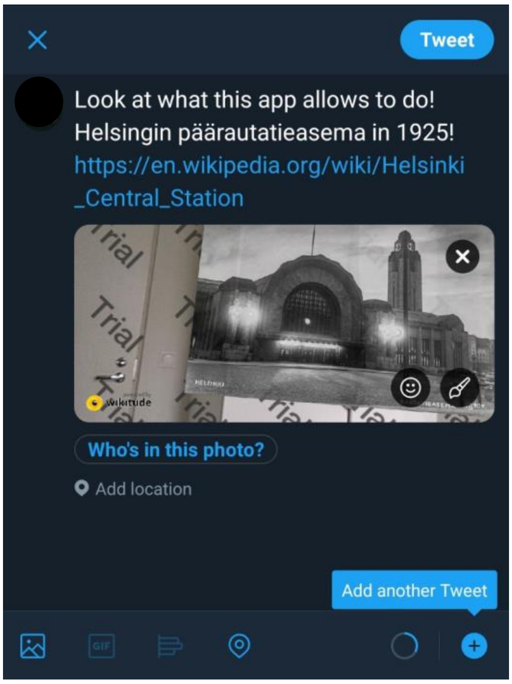

Figure 32 Test the Share button

5.3 Second approach

Wikitude offers the possibility to use custom plugins in order to add more features to the existing SDK. Plugins should be developed in C++ or Java (JavaScript SDK) or in python, C#, C++, Java or Objective C for the other SDKs. As it stands on Wikitude's website, a plugin has access to camera frames and information about recognized images – like pose and distance (Wikitude, 2019a). It then becomes possible to create a plugin which could analyse a camera frame and could try to find similarities with another image – such as an old photo – in order to find out where a superimposition could happen.

To do so, the thesis' writer made some research about existing libraries, projects and ideas which could help. The OpenCV (Open Source Computer Vision Library) library has quickly been considered as the best choice. It is an open source project which gives the possibility to develop computer vision applications and is being used by many different companies and projects. It mainly enables one to develop applications with OpenCV by using C++, Java and Python and those projects can be executed on Windows, Linux, Android and MacOS. (OpenCV, 2019a).

Due to a steep learning curve, this thesis' writer didn't have enough time to develop a whole plugin in C++, since they have no development experience neither with C++ nor with OpenCV. However, they could find several projects and tutorials to develop with python and OpenCV. In the end they could tweak several portions of code to end up with an algorithm to superimpose images according to matching points.

5.3.1 Open-sourced library

OpenCV provides an algorithm to detect and describe key points, Oriented FAST and Rotated BRIEF (ORB). ORB is an open-source alternative to patented algorithms SIFT and SURF which offers more or less the same results than the commercial algorithms (OpenCV, 2019b).

This thesis' author found a tutorial on Kaggle which explains how to use ORB to detect and match features between images (Elshamy, 2018). The implementation of this tutorial has been tested with two different locations which the application could has to deal with. The first one is in Switzerland (Figure 33 and Figure 34) and the second one is the main train station in Helsinki (Figure 35 and Figure 36).

Figure 33 Salvan (Switzerland) in 2017 (Jacquier, 2017b)

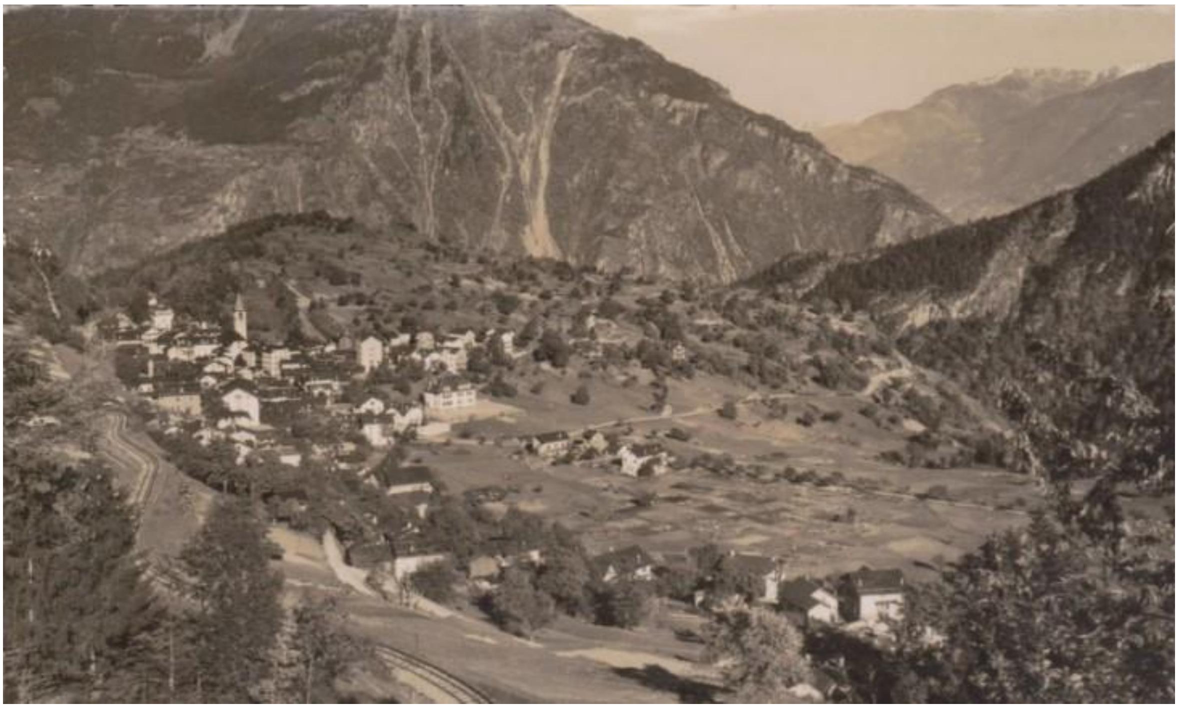

Figure 34 Salvan (Switzerland) in 1910 (Jacquier, 2017a)

The village expanded a lot in the gap of 107 years between the two photos. However, some big elements like mountains didn't change (or just a little bit). The photos represent the same place but are not taken from the same spot. This means that the angle and the scale are different, which could lead to a lot of problems when it comes to perfectly superimpose pictures. Indeed, one of the images should be resized and transformed to absolutely match the other one. However, since the current image cannot be transformed at all (as it would come from the live view) it would only possible to act on the old one.

On the other hand, Helsinki main train station didn't evolve a lot. The street changed a little bit, but the building looks the same between the two images.

Figure 35 Train station of Helsinki in the 1950s (Havas, 1950s)

Figure 36 Train station of Helsinki in 2019, photo taken by the writer

Using those two different locations to test the algorithm is meaningful as it would show how it works in a city as well as in a more natural environment. That being said, the algorithm developed with ORB doesn't seem to work really good, as Figure 37 and Figure 38 show. The train station photos have a lot of useless information (such as people) and the application tries to match points between people but doesn't match anything from the building itself. This obviously isn't the expected and desired behaviour. Even cropping the old photo – to remove all the people in it – or modifying the luminosity and contrast – to highlight the building details – doesn't help. The same kind of issues happens with the mountain village photos. No point is matched correctly.

Figure 37 Matching points with ORB (Helsinki Train Station)

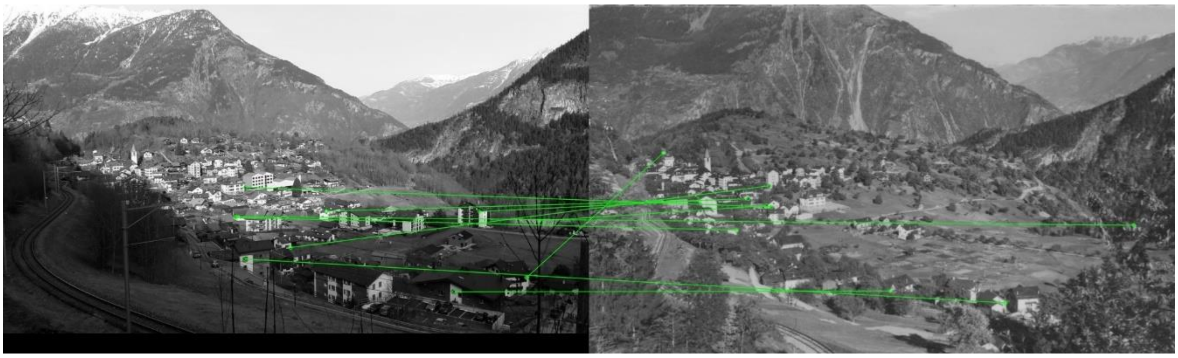

Figure 38 Matching points with ORB (Salvan)

After several attempts to tweak the algorithm and modify the photos to help the image processing, no satisfactory results have been obtained. In order not to lose too much time, this thesis writer decided to move on another track.

5.3.2 Using patented library

ORB has been created in order to offer an alternative to patented libraries: SURF and SIFT. Elshamy also explained how to use SIFT in his tutorial (Elshamy, 2018). This thesis writer tried this tutorial to see if the results were better. The same images (Figure 33, Figure 34, Figure 35 and Figure 36) were used in this test.

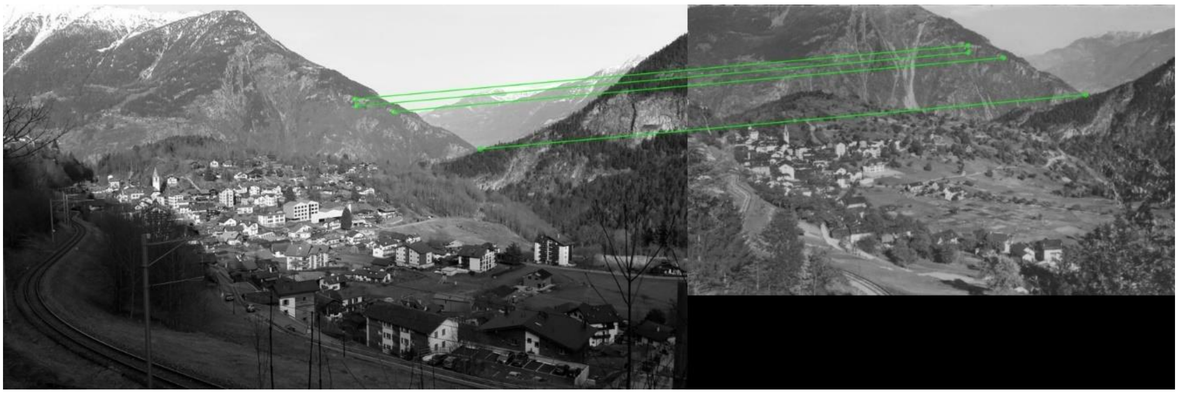

Figure 39 Matching points with SIFT (Salvan)

Figure 40 Matching points with SIFT (Helsinki Train Station)

Regarding Salvan, the matching points worked way better this time. The application managed to highlight some points in the mountains even if the angle is different. However, when it comes to Helsinki Train Station, the results aren't perfect. They surely are better than with ORB, but the matching points are not correct. The matching point on the roof of the old photo refers to the wrong side of the main entrance on the recent one. The same happens to the clock: the point on the old photo refers to its wrong side on the recent one. Nevertheless, the results are way better with SIFT than with ORB. The photos of the Helsinki Train Station have different angles, which also challenges a lot the detection of matching points (especially because the roof is way longer on Figure 36 than on Figure 35).

Considering that this is a good enough result for a prototype, there is still another step to implement: the superimposition. The idea is to calculate the origin point (top left corner) of the old photo in the current photo. In order to do so it is quite simple: take the coordinates of a matching point in the old image and subtract them to the coordinates of the same point in the current image. It works quite well for Salvan's example (Figure 41), as the matching points were correct, and the scale of the image is similar. On the contrary, the merged image of the Helsinki train station isn't absolutely conclusive (Figure 42). The wrong position is not a big surprise as the matching points were not correct, and the difference of size should be treated as well.

Figure 41 Merged images of Salvan

Figure 42 Merged images of Helsinki Train Station

Moving on with these first results, it is possible to think about developing a plugin which could try to find matching points between an old photo and the current frame provided by the SDK. As soon as the origin point of the old photo in the current one has been determined, it could be possible to know where to superimpose it in the SDK (thanks to the Tracking features). The first thing to do would be to decide which algorithm should be used (open-source or buy a license for the patented one). Then the work should improve the algorithm to define better what is a false-positive matching point and what is not and finally being able to determine the scale of the image to display the superimposition.

6 Evaluation of the result

6.1 Functional evaluation

The functional evaluation has been made during the whole implementation. The prototype has been tested on a OnePlus 5T running Android 9. Since the application is heavily related to GPS location, some of the tests and implementation parts had to be done in front of the Helsinki Railway Station. However, some tests could be performed at other locations, by using fake GPS data. After each addition of a new feature, tests were performed to quickly detect any issues. These tests are summarized in **Erreur ! Source du renvoi introuvable.**. Most of the points tested worked very well. As explained in the implementation part, the superimposition isn't always giving perfect results, but possible solutions are explored in the implementation part and in the discussion part. Small graphical glitches were detected during these tests.

First, the superimposed image tended to disappear while the application was running. After investigation, this was due to improper implementation of the scaling gesture. Second, when no POI was detected around the device, the popup showed successfully. However, the user could close it and access the live view. No action could be performed as the buttons were disabled. As a solution, the popup isn't dismissible anymore. Third, when the user closed the *More information* modal, the application could sometimes display an alert message explaining that the image resource couldn't be loaded anymore. The official documentation uses relative paths media resources (paths are relative to index.html's location), but after several tests, the use of absolute path got rid of all errors. Those were the biggest issues detected after the implementation of a feature.

Table 3 Test protocol

Feature to test	Expected result	Result
The application is asking for permissions at first launch	✓	✓
The application displays an error message if no POI's available around the location given by device	✓	✓
The application displays the default image at a specific location	✓	✓
The application superimposes correctly the image	✓	✗
The user can move, resize and rotate the image	✓	✓

The application shows a popup with more information when the user asks for it	✓	✓
The application allows the user to open a webpage from the more information popup to get detailed information	✓	✓
The application takes a picture of the superimposition and add it in the phone's gallery	✓	✓
The application allows to share a picture of the superimposition with a text to social medias	✓	✓

6.2 User Experience evaluation

In order to provide a solid evaluation, it was necessary to use a recognized tool. After several researches, the thesis author found out that the User Experience Questionnaire (UEQ) was probably a way to go with. UEQ consists of a survey developed back in 2006 by three German IT and usability experts. The survey contains 26 opposite adjectives pairs and the users evaluate each row with a number from 1 to 7, the two extremes sides of the scale (Figure 43) (Weschke, 2018).

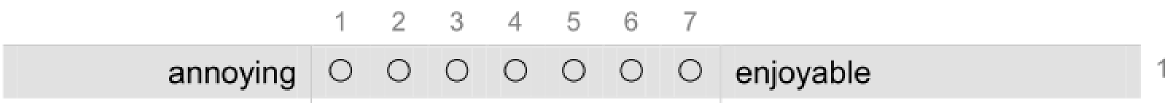

Figure 43 Example of a row of the UEQ (UEQ, 2019)

The survey covers a wide range of impression of user experience, allowing to measure usability aspects and user experience aspects. UEQ (2019) measures:

- Attractiveness: the impression of the product.
- Perspicuity: the easiness to use the product and learn its usage.
- Efficiency: the ability to solve tasks without unnecessary effort.
- Dependability: the user controls the interaction and it is predictable.
- Stimulation: the motivation to use the product.
- Novelty: the creativeness of the product.

Another good part of UEQ is that it provides an Excel sheet in which the only action necessary is to enter the answers provided by the users (UEQ, 2019). Finally, using such a tool not only allows to get a fast insight of the usability of an app but also to easily compare it to a concurrent one (Weschke, 2018).

Table 4 Profiles of people who tested the prototype

Users	Expertise level	Gender	AR Experience	Interest for app

User 1	Novice	Male	Social medias Video games 3D viewers Utilities	Minor
User 2	Novice	Male	None	Great
User 3	Novice	Female	None	Minor
User 4	Novice	Male	Social medias Video games 3D viewers Utilities	Great
User 5	Advanced	Male	Social medias Video games 3D viewers Utilities School projects	Great

5 users tested the prototype and then filled in the survey. The sample's size is reduced but already allows to detect a trend in the evaluation of the usability of the prototype. Table 5 shows the means results of the survey with values ranging from -3 (worst value) to +3 (best value). Overall the results are good and mostly similar between the people. The fourth person find the application a little bit efficient, where the second one finds that the stimulation could be improved.

Scale means per person					
Attractiveness	**Perspicuity**	**Efficiency**	**Dependability**	**Stimulation**	**Novelty**
2.67	2.75	2.50	1.75	2.25	1.75
1.33	1.00	1.50	1.50	0.75	2.25
1.83	2.75	1.75	2.00	2.50	2.75
1.50	2.50	0.75	2.25	2.25	2.00
2.00	2.25	2.00	2.00	1.50	1.00

Table 5 Scale means per person

UEQ provides graphs and explanation for the calculated results. Figure 44 shows the overall results of all categories measured by the test. The range is shrunk from -2 to +2 in order to avoid extreme answers. According to their scale, a value is considered as a *negative evaluation* below -0.8, as a *neutral evaluation* between -0.8 and +0.8 and as a *positive evaluation* if higher than +0.8 (UEQ, 2019). Knowing this, the user experience seems to convince the people who tested the prototype.

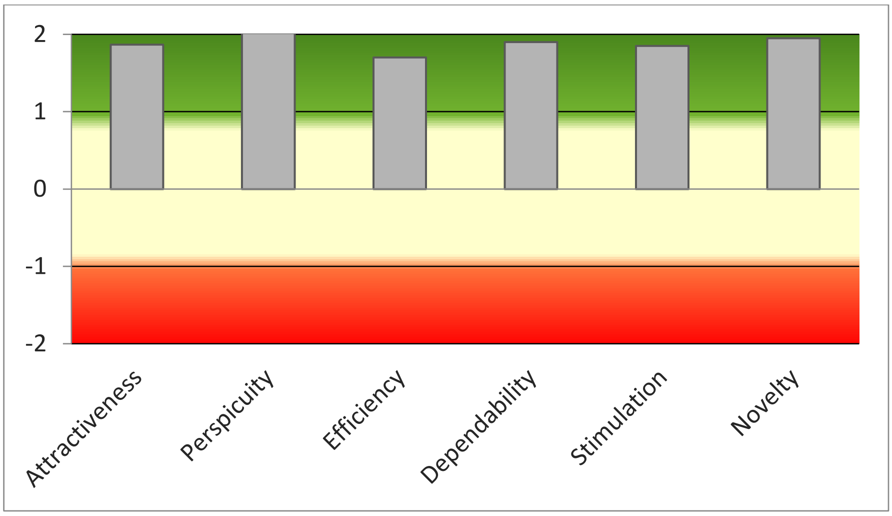

Figure 44 Results by categories

UEQ also contains a benchmarking tool, which allows to compare the user experience from the product with existing products. It contains data from 18483 people from 401 studies about several products such as business software, websites, social networks, etc. Figure 45 and Figure 46 gives the result of the benchmark. The results are very good, even if most of the *Excellent* values are close to be considered as *Good*. However, this would still mean that the prototype is simple enough to use for users.

Scale	Mean	Comparison to benchmark	Interpretation
Attractiveness	1.87	**Excellent**	In the range of the 10% best results
Perspicuity	2.25	**Excellent**	In the range of the 10% best results
Efficiency	1.70	**Good**	10% of results better, 75% of results worse
Dependability	1.90	**Excellent**	In the range of the 10% best results
Stimulation	1.85	**Excellent**	In the range of the 10% best results
Novelty	1.95	**Excellent**	In the range of the 10% best results

Figure 45 Benchmark table

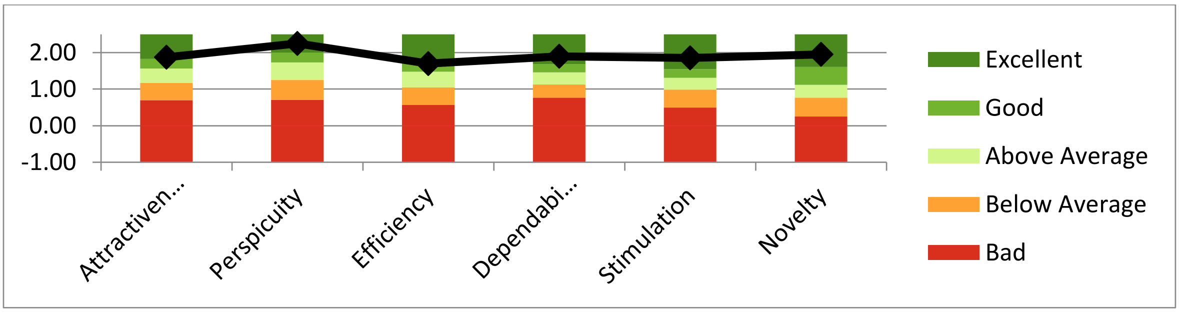

Figure 46 Benchmark graph

Despite the good results, this thesis' author noticed some things that could be improved during the tests. When the application is launched, there is a message explaining that the users can move the superimposed image to better fit the reality. Most of the users didn't pay attention to the message, as they were focused on the superimposition. Most of the times, they instinctively tried to move the image by themselves and noticed that it was possible. The users were globally satisfied with the product, especially with the *More information* and the *sharing* features. Saving an image on the device doesn't seem to be an indispensable feature according to the comments most of them made while using the application.

7 Discussion

The evaluation of the prototype showed that the users mostly find it easy to use. Users 1, 2 and 4 raised some issues with the gestures on the image as soon as the superimposition is done. Resizing and rotating the image works well, while moving it is sometimes a little bit messy. This is definitely a point on which the prototype should be improved. Some users (like users 1, 3 and 4) were also shy to press buttons present on the screen in the beginning, but as soon as the thesis' author told them to try all the buttons, they liked the features behind them. User 2 had small difficulties to understand the use of the buttons on the right of the screen (more information, take a screenshot, share). As a result of these feedbacks, a small tutorial explaining the application's features at its first launch could be useful. Finally, user 3 was wondering why the watermark "TRIAL" was visible on the screen. After a small explanation, it didn't bother the user anymore. Overall, the feedbacks were satisfactory, provided that it is currently just a prototype.

Moving on a technical discussion, the prototype implemented for this thesis shows the limits of Wikitude in the field of geolocation-based AR without pre-registered target for image recognition. On the other hand, the use of OpenCV seems to give a better accuracy in the matching of images – provided that the real environment still has some existing points on the photo. The author of this thesis unluckily hadn't enough time to implement a C++ OpenCV plugin for Wikitude, as the time needed to learn Wikitude's and OpenCV basics was quite important. Furthermore, they have no basics in C++ development, which would have increased the time needed for such a work.

In consequence, combining the two technologies should give better results. The geolocation features provided by Wikitude helps to reduce the number of possible photos around the user. This solution is only limited by the accuracy of the geolocation of the device: if the geolocation isn't perfect, the photos can't be positioned at the good place. Adding a plugin capable of matching points between reality and a photo would definitely help to build a more robust application. Indeed, if the geolocation isn't perfect, the application would at least get the good monument/place/building that should be rendered and then the plugin would help to superimpose at a better location.

On the other hand, the development of a plugin should also consider the use of automatic geolocalization. Knowing that this technology has made spectacular improvements for urban environments in the past decade (Saurer, Baatz, Köser, Ladický, & Pollefeys, 2016), this could be a great help as GPS can have some difficulties in cities (Piasco, Sidibé, Demonceaux, & Gouet-Brunet, 2018). On the other hand, automatic geolocalization still encounter problems in changing environments, such as nature – because of the different seasons for example. In this case, Digital Elevation Models (DEM), like SRTM, appears as a good solution: matching the skyline of an image with data coming from a DEM may give good results. Saurer et al. (2016, p. 224) reached 76% and 88% of recognition rate during their tests on two different datasets in Switzerland, which shows that the development of such a technology is on the good track.

Developing a plugin raise the issue of calculation. For instance, not all phones would be able to analyse the images, compute the matching points and know where the image should be overlaid in a sufficient time. Using an external server that would do all the calculation could become a possibility, but then the problem is that the mobile application would depend on an internet access, which pose several problems among roaming, zones without mobile connection, etc… However, with phones becoming more and more powerful, the need of external service for this kind of application could decrease.

This thesis shows that AR can be used in historical and touristic contexts and that the technology is existing. However, there is still a lot to do in terms of position calculation (device localization and image position). This work also highlights that existing frameworks are useful to begin with, but their limits are quickly reached in terms of features and require external tools, which permits to think about directly using lower-level libraries (for example OpenCV) to develop such an application.

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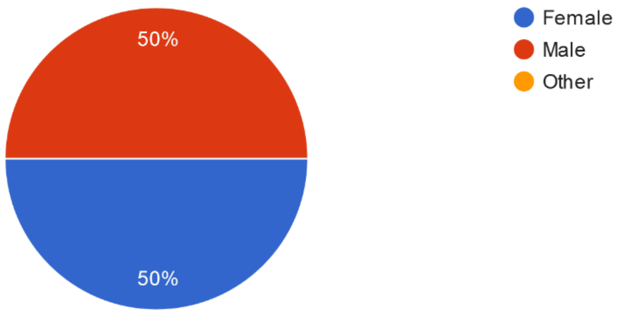
Appendices

Appendix 1. Survey results

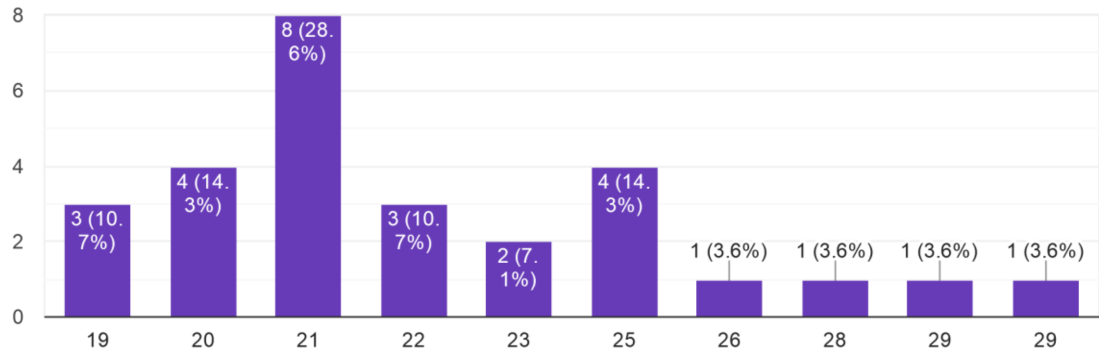
What is your gender?

28 responses



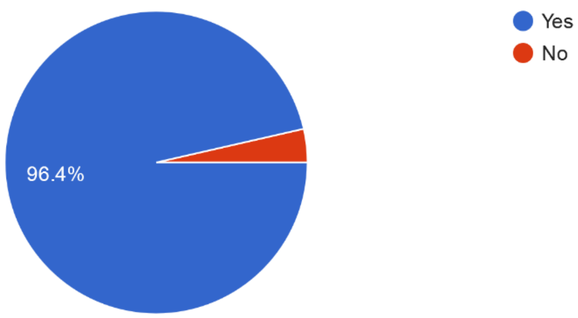
How old are you?

28 responses



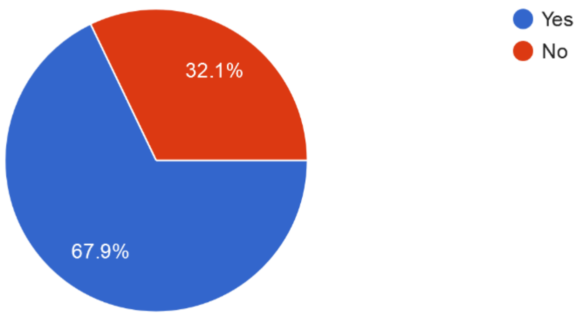
Do you know what Augmented Reality (AR) is?

28 responses



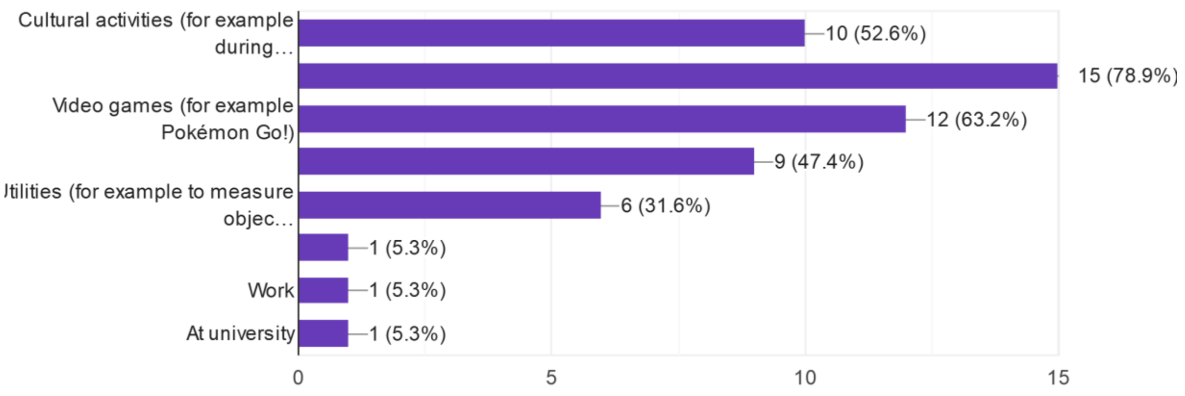
Have you ever used any kind of AR?

28 responses



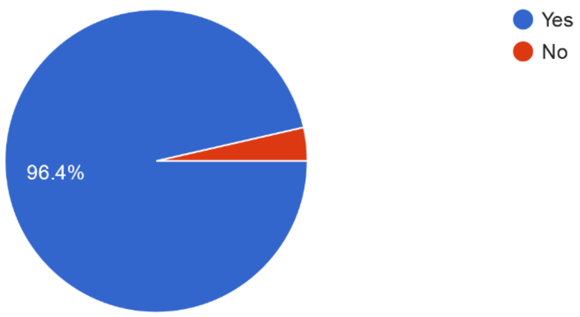
In which context have you used this technology?

19 responses



Would you like to use this kind of application?

28 responses



Would you like to have specific features in this application?

27 responses

No

To be able to go the web site of the location if existing and be able to see a small description of it. To know about interesting facts or fun facts about the location to know if some other places could be like this place or share a history with this place

Yes

What kind of features?

No, I don't see it necessary

setting the year

Maybe a little text to display so interesting information related to the building we are looking.

The possibility to move the phone and have 360 degrees of vision of the building

I think the best features you can develop are good voice and sound effects

Different time zones, So Maybe also a feature where you can see How ancient buildings were in their actual time period of existence

Maybe different layer that could be switched on and off, containing different eras (for a building that was renovated multiple times).

Having the possibility to have many images across the time if available and links to know more about the building

No idea

- the option to see the building/place etc. at different times (e.g. 10 years, 50 years, 100 years ago)

Yes, a place when people can add their new / old pictures to be able to see more historical picture... And to share maybe a short personal story with it

To have a timeline or specific years to decide on what time you want to see the building at

To get the story behind this change

Des informations sur ce que l'utilisateur voit à travers son téléphone (par exemple s'il y avait un bâtiment d'époque, des informations et dates concernant l'histoire de ce bâtiment...)

It would be great to have historical information about the places, buildings, etc.

I don't know

Yes, maybe some personalized features.

Display dates or text with key information

Non

It would be interesting to be able to take the picture with the overlay of virtual reality, so that you can read the information about the monument sit and relax.

Do good picture for Instagram ;)

Sensors

Why?

1 response

I won't spontaneously open the app to observe the evolution of a building

Appendix 2. Interviews

Structure of interviews

Quick presentation of the work (not too long, people already answered the survey)

Ask these questions:

- How do you feel about AR used in historical and cultural contexts?
- Could you explain a bit more what you meant by [interesting answer to the survey]?
- Could you describe your ideal workflow of the application?
- Do you think any social features should be included?
- How would you feel about favourite items? (recommendation to other users, …)
- Why would this application interest you?
- Anything to add? Any new idea from this discussion?

Thank the person

Interview 1

Q: How do you feel about AR used in historical and cultural contexts?

A: When I read your concept, with historical photos, it can be very interesting to have some superposition if images, some floating text to throw the user's attention to some details that you maybe couldn't do. If you had a guide who would tell you "look at this window, this was destroyed during the Second World War", you could have all of this without a guide, just with AR, and I think that it is really interesting.

Q: Could you explain a bit more what you meant by "display dates or text with key information"?

A: Yeah, if you look at a statue for example. You could have a floating text telling the name of the statue, the dates and like I said, draw the attention to some element of the statue, and if it is not a statue to the building or anything, just to add a little bit of history to the piece of art.

Q: Could you describe your ideal workflow of the application?

A: I imagine something light, where perhaps you just open the camera and you don't really have to select anything. You get the information as soon as possible. It could also have some menus where you could tweak some filters.

Q: Some people thought it could be a good idea to help people to find "augmented spots", by showing them directions. What do you think of it?

A: Why not, as soon as it is user friendly.

Q: Do you think any social features should be included?

A: It would be a plus but wouldn't be necessary, as you do that to learn things by yourself, it may be cool to share that with other users, but I don't think that this should be the primary objective of the application.

Q: How would you feel about favourite items? (recommendation to other users, …)

A: Yeah, why not! I haven't thought about it. If you visit a city or some place, you could see among your favourites spots some places that you've already visited, and you can go back there, and this would be useful if you visit the city a second time.

Q: If a monument has a lot of favourite tags, should it be proposed to other users?

A: Yeah, this would be perfect.

Q: Anything to add? Any new idea from this discussion?

A: The idea of favourite is really interesting; I haven't thought about it. Tell the users which places are the most beautiful, the most special, I think that this would be a nice addition to the application.

Interview 2

Q: How do you feel about AR used in historical and cultural contexts?

A: I didn't have any experience with AR in historical context, so I have no clue what it is about, but if you propose me this application, I'm not sure I would download it, because I don't really see the point of it and I prefer visit the place in real and see how the building actually is.

Q: This application would force you to go on the location and then you start the application, so you can see how it was before, on your phone. And if you look above your phone, you can see how it is currently. So, you can see how it changed, how wars destroyed stuff.

A: Would it be a tour in the city?

Q: Not a tour, you just have to go to the location so you can see a superimposition over the real state and then see the differences just by looking at your phone or at real life.

A: This is more interesting then! I didn't really understand the purpose of this application.

Q: You said in the survey that you wouldn't spontaneously use the application, but now that you understand the concept better, would you use this kind of application if you had the opportunity to use it?

A: I think I would try it, I'm not sure that this would become a habit. Once or twice could be interesting. I think it can be very funny with your grandparents because they would be very amazed by this application.

Q: Yeah it is exactly why I thought about this idea. As I was a child, my grandfather was always explaining me how some places were when he was younger, how no buildings existed at some places and I couldn't really imagine it, because I had no pictures of it, just a subjective explanation of someone who tells how it was from his point of view.

Q: Do you think any social features should be included?

A: Share on social medias the before and after?

Q: Yeah for example, just the sharing process.

A: Yes, I think social media is a really big tool for young people and this could help your app to be developed and get popular.

Q: How would you feel about favourite items? (recommendation to other users, …)

A: It would be like "MyHelsinki" list in a way, and I think it is a really good option because when people see what others are doing and you've read good reviews on an activity, you want to go to a place, so it would be a good advertisement for the good places.

Q: So, you think that we should also include reviews in the application?

A: Yes, reviews on the buildings.

Q: Now that you've changed your mind, why would this application interest you?

A: Would it be "static", or would you have a video of how the building was before?

Q: Currently the idea would be to stay static, but why not later add morphing between photos, so you can see the evolution.

A: If you can do both, it is interesting, because you wouldn't want to spend too much time at a place. Either pictures or videos that you can share with your friends. This would be also interesting to see how people were living in a building before, for example a farmer's life, a worker's life, etc....

Q: Anything to add? Any new idea from this discussion?

A: Not yet.

Interview 3

Q: How do you feel about AR used in historical and cultural contexts?

A: I think that AR can be a real plus in historical context, as for museums or other places. Making a museum more lifelike to see what it used to look like can really motivate especially young people, who could be more interested in history and maybe create new career.

Q: You mean that this added value could interest more young than old people?

A: In my opinion yes, young people are more prompt to be touched by this as they probably haven't already learned what was there before and this can be their first approach to new things.

Q: Could you explain a bit more what you meant by "To know if some other places could be like this place or share a history with this place"?

A: I was thinking especially about Valais or Greece, when you could see an old place and pose a picture on it, maybe you could have some kind of concepts, some architectural information, and even find some other buildings/artworks built by the same architect or artist nearby. People could be interested in going to similar places. In Greece maybe you could get information about other temples, other Gods.

Q: Could you describe your ideal workflow of the application?

A: Open the application on my device, then I can see the place in front of me with some hotspots on which I can click or directly see how it used to be, as I would have defined that in the settings.

Q: So, you'd like to have two different views: one directly with the superimposed photo and another with just points on which you could click to get more information?

A: If there is only one view, I'd like to have the superimposed view, but if there are multiple hotspots, I'd like to be able to choose between older or different spots.

Q: Imagine we had a wheel we could roll at the bottom of the app, so we could change the years if many different are available?

A: That would be really good too!

Q: Do you think any social features should be included?

A: I don't really use social medias, so I wouldn't share with other people. It could be nice to see what other people saw, but it would mainly be for my own use, without sharing it with other people.

Q: How would you feel about favourite items? (recommendation to other users, …)

A: I don't think I would need favourite place, because if I go somewhere, I can see the pictures, but if I don't go there, I can't see the pictures. Going there would be like pinning a spot on a map. Except if I go there, I wouldn't be able to see again the augmentation, so I don't see the point in favourite items.

Q: But if you put in your favourite, or give a good rate to the spot, then it could be recommended to other people. Would you like to receive some recommendation?

A: I could like to receive some.

Q: Why would this application interest you?

A: In a touristic and curiosity way. Just to satisfy my curiosity, discover some new stuff and maybe to learn some new things too, in a cultural way.

Q: Anything to add? Any new idea from this discussion?

A: Not really.

Interview 4

Q: How do you feel about AR used in historical and cultural contexts?

A: I think it is an interesting tool in places like museum, or places like that, where you can see situations from the past, and feel you're taking part of it. This is interesting how technology can make people know better how the past was. It would be nice, if you were in a museum about World War 2, that you could put glasses of Virtual Reality and you end up in the middle of the battlefield or in the middle of somewhere where something is happening.

Q: This is virtual reality; AR is different because you keep the regular world and just add stuff to it.

A: You see the same things with added information?

Q: Yes, this is AR. But you can still use it in a historical context!

A: Yes, maybe you could look at a field and then AR shows you how it was in the past, if there was a building in the past, etc…

Q: That's exactly the point of this application!

A: This would be interesting and funny! [laughs]

Q: I've seen that you've never used any AR in your life, so this is quite interesting for this research. When the prototype will be done, would you like to test it if it is working?

A: Of course!

Q: Do you think any social features should be included?

A: Yeah of course, sharing funny or interesting things with friends is always nice.

Q: Do you think this could be important for the app to get known by many users?

A: I don't know.

Q: How would you feel about favourite items? (recommendation to other users, …)

A: It would be nice to make it easier to see the place!

Q: Yes, but you would still have to go to the place to be able to see the augmentation. But if you put in your favourite, or give a good rate to the spot, then it could be recommended to other people. Would you like to receive some recommendation?

A: Of course, looking at what other people like can create some attraction to a place. If many people see that a place has a lot of favourite tags, then they could think “Wow, this place has something, I should go there to see it!”.

Q: My next question was: “Why would this application interest you?”, but you already answered this before in the interview

A: Yes, exactly.

Q: Anything to add? Any new idea from this discussion?

A: No, I don’t think so.

Interview 5

Q: How do you feel about AR used in historical and cultural contexts?

A: I think it is an interesting thing and that it can really bring value to the experience of historical places for example, and it can really widen the things that you discover.

Q: In the survey stands the question “which kind of features would you like to have in such an app”. Could you explain a bit more what you meant by “setting the year”?

A: To see places in a different year, to see the historical development of places, from different ages, because sometimes places change over the time, there is not just like one historical step but some steps in-between and I think it could be interesting to see this.

Q: So, if for example there are several pictures of one year, you’d like to be able to choose the year…

A: …Yeah…

Q: … and then see the still image?

A: Yeah! For example, a castle in year 1500 and how it looked like 300 years later or something.

Q: With paintings or stuff like that then?

A: Yeah.

Q: Could you describe your ideal workflow of the application?

A: I think I would take it out and the best way would, I think, that there is directly a button where I can switch to my camera and when the AR-thing is implemented and then I just point with the camera on the building and then it shows the picture according to the location where I am. I think that this would be the easiest way.

Q: Not directly the camera but you’d prefer to have a button to start the view?

A: Yeah it depends on the application, if there is any further content, when the application is just about the AR-thing, without any other feature, I also could imagine that the camera directly opens, like Snapchat for example. I think that this would also be a good thing!

Q: Do you think any social features should be included?

A: Yeah, me personally I’m not that social media guy so I don’t share that much, but I think that especially for the promotion of the app, it would be great to be able to share a picture, maybe also a historical picture, due to integration of social networks like Facebook or Instagram.

Q: How would you feel about favourite items? (recommendation to other users, …)

A: I think that this sounds like a good idea, like a little bit like a TripAdvisor feature.

Q: Why would this application interest you?

A: I actually had it, for example currently here in Helsinki, I’ve visited some places and I was really curious how these places looked like some years ago or some hundred years ago, so I really actually had the feeling that it would be nice to have some feature like this. To see like big places in the historical development.

Q: Anything to add? Any new idea from this discussion?

A: Hmm... No actually I think that’s it.