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OFFICE OF THE FUTURE

The Use of Augmented Reality in Personal Information Management

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"This master's thesis came about (in part) during the period in which higher education was subjected to a lockdown and protective measures to prevent the spread of the COVID-19 virus. The process of formatting, data collection, the research method and/or other scientific work the thesis involved could therefore not always be carried out in the usual manner. The reader should bear this context in mind when reading this Master's thesis, and also in the event that some conclusions are taken on board."

Abstract

Over the last few years we have been seen an increase in the amount of information that each person needs to store on a daily basis. Thanks to new technological advances, we have moved from a purely physical information management to one in which physical and digital information must be managed simultaneously, as doing without physical information and documentation is not yet an option. On the other hand, it is worth mentioning the great change in people's daily habits, which have been affected after the COVID-19 pandemic. Previously it was possible to have some kind of distinction between books and documents that belonged to the user's personal life and those that were strictly work related, but now both spaces have been combined, as we have all had to learn to live in a society where teleworking is part of our new normal. Nowadays, finding a document or book in our office may require extra time and organisation that we were not used to before.

This thesis aims to use augmented reality in the management of personal information within a workspace. With this idea in mind, a study has been carried out on the solutions that have been proposed in the past regarding this issue, and a solution has been worked on that could be applied in the current context and that does not require the use of devices that are complicated to install and that could be invasive for the user.

The prototype that has been worked on, which would give a glimpse of the final solution of this thesis, uses a web application, with which the user can interact, which can be accessed from any browser and without the need to install an extra application, this also increases the scope of the prototype, as the operating system of the user's device is not a limiting factor. To be used, the web application requires the user to enter the map of their workspace, or the place where they store their books/documents and indicate the specific places where they are located, as well as the books/documents that are in that space and the place where they are stored. In this way, when the user needs to find a book/document, they only have to enter the title and the application will guide them around the office, using augmented reality, until they find what they have been looking for. This prototype has been presented to different types of users, with different backgrounds and in different age ranges, to test the feasibility of the user experience.

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First of all, I would like to thank my promoter Prof. Dr. Beat Signer for all his support, guidance and help throughout this Master's thesis. He was always there to answer my questions and to give me advice when I got stuck.

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Contents

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Introduction

Offices and the work that takes place in them are an essential part of our daily lives. They are places where ideas are conceived, knowledge is shared and information is generated, among other things; they are places that, being so important, are often the origin of the information we have, but at the same time they are places where we store it, when it is in physical format. Over the years we have been able to observe the transformation that has taken place in offices. In the early 1800s all documents had to be folded and stored wherever there was a little space. This way of storage changed radically in 1898 when Edwin G. Seibels invented the vertical filing system, after realising that it was more efficient to store documents in long envelopes that could be organised vertically in a cabinet [8]. This invention allowed documents to be organised in a structured way without being damaged in the process.

However, recent years have seen a huge increase in the amount of information available and the different formats in which they can be found, with technology playing a key role in this development. Although at the time the design of vertical cabinets was a great innovation, as the years went by and the number of documents increased, this solution began to show certain shortcomings, as the storage of all these documents sometimes required rooms dedicated only to this use.

Additionally, searching for and locating a specific document required the time and energy of the office staff, who had to dedicate themselves to this activity instead dealing with more important duties [2].

The technological advances of recent times have had a clear impact on everyone's life and daily activities. Tasks that used to take days or weeks can now be done almost immediately. Of course, offices were not excluded from the great advantages that technology provides. This technological improvements have allowed much of the information previously held only in physical format to be digitised, thus dispensing to a certain extent with the need for large cabinets and giving a new use to all the space that could be freed up. Nowadays, even though information is being handled mostly in a digital way, there are still cases where people need to use physical documents which may or may not have a digital copy. Many companies still have their documents in folders stored in shelves, or books concerning a specific topic, which are still used every now and then. In this regard, it would be important to locate the mentioned documents in an automated and efficient way.

It is quite clear that in recent years we have been exposed to new tools and applications that have improved, in some way, our lifestyle and the way we carry out our activities. But at the same time, the increase in the amount of information we receive on a daily basis and all the information we have accumulated over the years, creates the need for document management that meets today's needs. The amount of information generated on a daily basis is staggering; in 2020 it is estimated that on average 190 million emails were sent per minute [23], which only gives us an idea of the amount of data generated per hour.

1.1 Applying Document Tracking and Augmented Reality for Document Management

A frequent problem that people have struggled with at some point in their lives is trying to find a specific document or piece of information in a pile of documents or papers. This activity can consume a lot of time, especially when all the documents are mixed and they do not follow any pattern.

Why use *augmented reality?* The evolution of this technology in recent years has been by leaps and bounds, since its inception in 1968 with the cre-

ation of the head-mounted display system by Ivan Sutherland with the help of Bob Sproull [9]. Later this technology was used in certain applications of the Air Force and NASA. However, it was only recently given the term *augmented reality* in 1990, by Boeing researcher Tom Caudel. Despite the advances at this technology, it was not until 2009 that interest in this technology increased due to its integration with smartphones and the possibilities this offered. Finally, it was in 2016 that augmented reality was catapulted into the mainstream thanks to the launch of Pokemon Go[1] a popular game that was created in collaboration with Niantic[2], Nintendo[3] and The Pokemon Company[4], which uses geolocation to locate, capture, train, and battle virtual creatures called Pokemon[5] [3].

Currently, augmented reality is being used in many sectors, such as construction and manufacturing, to improve the user experience. One concrete example is that thanks to this technology it is possible to see the design of an office long before it is finished or remodelled. So the question is, why not include augmented reality to the work environment? With the new and rapid changes that have occurred in recent months, due to the pandemic of COVID-19, the whole world has seen the need to make a radical change in their work routines, with the new regulations of social distancing and encouraging to stay at home as long as possible; both those people who already had to partially work some days at home and some days in the office, and those who had to go to the office every day of the week, have had to change to a 100% remote work.
This change has resulted in people having to combine personal life with work life, therefore, the location of physical information within a given space becomes necessary, because now not only have books and professional documents in one place, but also the personal tastes of each user.

1.2   Problem Statement

How much time do people usually spend looking for misplaced documents or books? How helpful would it be to have some sort of guidance when looking for some specific information? Disorganisation within an office environment can lead to a waste of working time and leaks in the concentration of a

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[1]`https://pokemongolive.com/en/`
[2]`https://nianticlabs.com`
[3]`https://www.nintendo.com`
[4]`https://www.pokemon.com`
[5]`https://www.pokemon.com/us/pokedex/`

person. Just to give an example, in 2018 office workers across the UK wasted over one million hours a week searching for documents [25]. Taking this into account, a single person or a company can be seriously affected, in terms of finances or productivity. Even considering only a single office, it is easy to imagine all the information a person might have stored over the time.

1.3 Research Question

Having in mind everything that was mentioned above, the main question of our research is:

How could we integrate the benefits of augmented reality and a user-friendly web application in an office environment, in order to track documents and books that were previously registered in the personal library of the user, as well as getting an insight into them?

To be able to answer this question, there are a couple of questions that have to be answered as well

- How could we retrieve information from a book using current APIs that are available in the market?

- What is the best approach for the design of an augmented reality application, taking into account a user preferences?

- What are the best tools available in the market nowadays, to implement an easy and user friendly application?

- How to implement a solution that allows the location of a specific document within a pile of documents on a desk to be tracked?

1.4 Benefits and Solution

The purpose of this Master's thesis is to present alternatives related to a frequent problem in an office environment which is the management of personal information, both digital and physical. An ideal office of the "future" should use techniques to track objects, documents contents and their structure.

Different approaches will be studied in order to evaluate their feasibility regarding these principal components. In this thesis, different types of tools and technologies will be tested to allow a person to manage the information

stored physically and virtually in their office. For the purpose of this research, a prototype will be developed using the tools and technologies which will be selected after an evaluation. Several users will then be able to test the feasibility of the final prototype, and test the solutions that were found. The approach and results of this will be discussed throughout this thesis. One of the key challenges in this research is the location of books that were registered within the application. In an environment of relatively small proportions, a conventional GPS would not serve to track the documents accurately, so for this reason we will test the location based on tags strategically positioned, which will guide the user through the office, using augmented reality. Another significant challenge will be the integration of augmented reality and the use of REST APIs to show the user the details and general information of a book.

1.5 Contributions

In this thesis, a proposal will be made on how to guide a user towards an object of interest using augmented reality in an office environment which will be evaluated by means of a prototype and a user interface. As mentioned above, there are several applications of augmented reality. In this sense, this study provides an insight into how this technology can be applied and what are the possible limitations. In addition, the present thesis will describe the different types of augmented reality used in the solution proposed along with the algorithms applied to guide the user. The technologies involved include the use of image tracking and location based augmented reality using a web interface that can be accessed using a URL. Moreover, a study of the implementation of an Indoor Position System will be made where the user can be guided towards an item of interest in an office environment.

With the results obtained, companies or individuals would be able to analyse the feasibility of using augmented reality resources to track their documents within an office environment and how augmented reality along with other components can be used to achieve this purpose. In case of implementing the recommended solution in this work, the users who came to use the application would face a new way of finding books and/or documents in an office, as well as creating a link between their physical and digital document. On the other hand, the general public will be able to access a study of the methodologies and tools that have been used to date for the tracking of documents and objects within a closed environment with a limited surface.

- In this thesis, different types of tools and technologies will be tested to allow a person to manage the information stored physically and virtually in their office.

- A prototype will be made using the tools and technologies which will be selected after an evaluation. Several users will then be able to test the feasibility of the final prototype, and test the solutions that where found. The approach and results of this will be discussed throughout this thesis.

- A study will be made about possible solutions that allow the user to find the location of a specific document within a pile of documents on a desk. This can then serve as a foundation for future researchers who are interested in further developing projects related to the 'office of the future'.

2

Background and Related Work

As mentioned in the previous chapter, one of the objectives of this thesis is the study of the benefits of augmented reality for further application in an office. To this end, in this chapter we will give the context about what exactly augmented reality is, the different types of augmented reality and an overview about document tracking. On the other hand, it will also provide an overview about current technologies for mobile application development and their integration with tools that allow the development of augmented reality applications. Finally, a study and analysis of all currently available applications and literature related to this thesis will be presented.

2.1 Augmented Reality

The first appearance of augmented reality was in the 1950s, when Morton Heilig, a cinematographer, though that a person should enjoy the experience of going to the cinema by involving all their senses in an effective manner. That is why in 1962, he built the *Sensorama* (Fig 2.1), a prototype that delivered smells, sound, vibration and visual to the user. This device was not computer controlled, but this was the first attempt of having a real experience with added data [6].
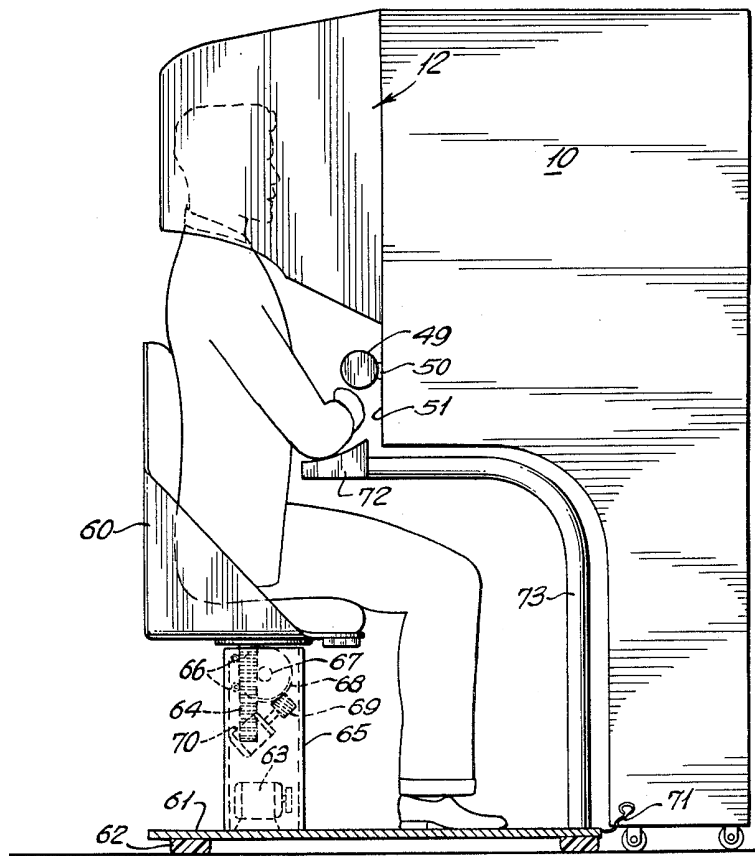
Figure 2.1: Sensorama [6]

A few years later, in 1968, Ivan Sutherland invented the first an optical see-through head-mounted display (Fig 2.2), this was the first augmented reality device [32].
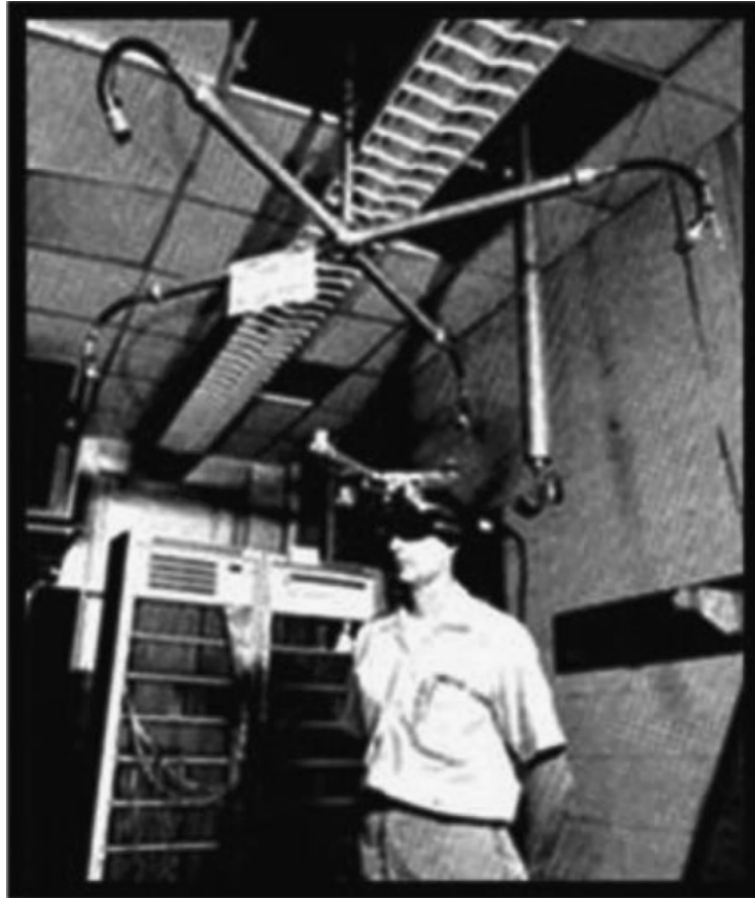
Figure 2.2: Head-mounted device [32]

Augmented reality can be defined as an augmentation or enhancement of the physical real world by adding virtual information generated by a computer; therefore, the user has an interactive experience of the real world. It differs from the concept of virtual reality in the sense that this approach will be *closer* to the real world as it does not attempt to create a new reality but just augment some components to it [28]. These virtual components contribute information that the user would not be able to perceive with their senses. There is not a restriction about a type of display related to augmented reality, these can vary from cellphones to headsets.

There are three basic features that have to be fulfilled by an augmented reality system:

- The combination of real and virtual worlds.

- A real-time interaction between the user and the system.

- An accurate registration in 3D of real and virtual objects.

The perception of the natural environment is altered by overlaying computer generated information onto the normal environment of the user. This generates an immersive experience for the user without replacing the user's perception of the real world, which actually happens in virtual reality using computer based simulations.

Computer vision plays a very important role in augmented reality, since it can render three dimensional objects, based on the images takes by tracking cameras pointing at the same viewpoint. The methods of computer vision that usually are used by augmented reality have two stages: tracking and reconstructing/recognising. The techniques used for the tracking of objects can be divided into two main classes: feature-based or model-based; the difference between these two methods is that featured-based methods find the link between two-dimensional image features and their corresponding three-dimensional world frame coordinates, while model-based methods make use of a model of the features of the tracked objects, this model can be a CAD model or a two-dimensional template. If the mentioned relation is found then a projection can be made of the feature's three-dimensional coordinates into the ones of the two-dimensional image. This can be done by minimising the distance to the two-dimensional features [32].

2.1.1 Augmented Reality Interfaces

The creation of user-friendly applications, which allow a smooth interaction between the user and the virtual content, is one of the most important aspects to take into account while developing an augmented reality application [32]. There are four main ways of interfaces in augmented reality:

- *Tangible augmented reality*: An interaction with the real world is supported by these kind of interfaces, which make use of physical object and tools. One big example is IKEA Place[1] the application of IKEA

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[1]`https://www.ikea.com/au/en/customer-service/mobile-apps/`
`say-hej-to-ikea-place-pub1f8af050`

that allows users to go through the furniture available in the store, select an item and place it virtually in their own place.

- *Collaborative augmented reality*: Multiple displays are supported by these interfaces, this aim to improve remote and co-located activities, given that remote augmented reality can integrate multiple devices and locations. These kind of interfaces are mainly used in teleconferences, medical applications and maintenance support.

- *Hybrid augmented reality*: These interfaces give the possibility to integrate a wide variety of interaction devices, such as devices that display the virtual object and at the same time produce visual and auditory feedback, providing a platform for unplanned activities.

- *Multimodal augmented reality*: These are the most recent kind of interfaces. A combination of input of real objects with naturally form of language and behaviour is possible through these interfaces. Multimodal interfaces let the user decide the type of interaction they prefer to use depending on the context.

2.1.2   Types of Augmented Reality

Augmented reality can be classified in several ways based on the main application [30]. In general, it is possible to distinguish 6 different types of augmented reality, grouped in two different categories:

Category	Type	Examples	Characteristics
Triggered	Marker-based: Paper	String and Blippar	Paper marker activates stimulation.
	Marker-based: Object	Aurasma	Most objects can be made into markers.
	Location-based	Yelp, PAJ and Instagram	Overlay of digital information on a map or live camera view. GPS may activate stimuli.
	Dynamic Augmentation	Video Painter	Meaningful, interactive augmentation with possible object recognition and/or motion tracking.
	Complex Augmentation	Google Glass	Augment dynamic view and pull internet information based on location, markers, or object recognition.
View-based	Indirect Augmentation	Wall Painter	Image of the real world augmented intelligently.
	Non-specific Digital Augmentation	Swat the Fly and Bubbles	Augmentation of any camera view regardless of location.

Table 2.1: Summary of augmented reality categories and types (extracted from [30])

In this sense, the work of the presented Master's thesis will focus more on marker and location-based augmented reality.

Marker Detection for Augmented Reality

Over the years, planar marker systems have been used in conjunction with augmented reality, due to the versatility of their use. The application of such markers starts with the simple storage of certain information, which can be scanned and used later, for example in industry, and lately even in the hospitality sector. The last few months have seen a large increase in the latter

sector, as due to the COVID-19 pandemic, many restaurants have had to pass over conventional menus, to start using markers containing information and thus dispense with possible sources of contagion for customers. But this type of marker has also been used for localisation, using augmented reality (e.g. ARToolKitX[2] or ARTag[3]). The design of the markers to be used depends very much on their intended application, as one can see in Figure 2.3.
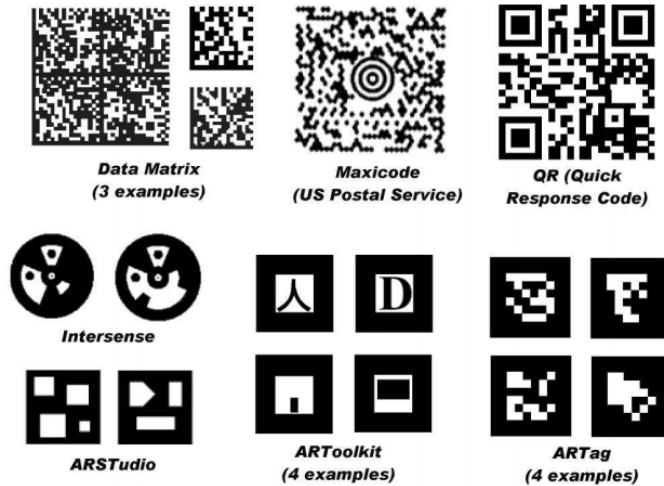

Figure 2.3: Different markers (extracted from [31])

The algorithm for marker detection is executed in three steps: line detection, line extension and line grouping. Line detection is done using edge pixels, where line segments must be found in a sampling grid and then linked together to obtain longer lines. Line extension refers to the fact that all detected lines must be extended, based on the gradient information, in order to get the full size of the lines. Finally, in the line grouping step, the previously extended lines are grouped together, forming quadrangles [33].

2.1.3   Outdoor Tracking Using Augmented Reality

Location-based AR has been used to track objects in an outdoor environment. This is a marker-less approach in the sense that the user only needs to be in the required position for an object to appear in a specific application. There are several applications using this approach such as games or

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[2]http://www.artoolkitx.org
[3]https://ieeexplore.ieee.org/document/1467495

tourism. Moreover, this kind of tracking can be applied in several ways. For instance, a group of researchers [38] applied gyroscope measurements that handled fast motions of the user, tracking of gravity and magnetic fields to deal with drifts and back-stores of reference frames. Another research [26] applied outdoor tracking with immersive AR tracking outdoor buildings. A parliament building in Canada was used to test this approach. The main objective was to show alternatives on how to overcome common problems of augmented reality using outdoor tracking which include variability in the light, changes in the environment, weather and some obstructions.

2.1.4 Indoor Tracking Using Augmented Reality

Augmented reality can be used to track objects as well as environments in an indoor space such as buildings or floors. This approach can be implemented in several ways. As in any indoor tracking system, beacons such as wi-fi or Bluetooth antennas can set up in the room or building to apply triangulation algorithms in order to track the desired object. However, there is another approach that does not use beacons but markers. There are some research projects that use markers to implement an indoor tracking system. For instance, a group of researchers [39] combined Augmented Reality, Mobile, cloud and wearable computing to track an object within a building. The main idea is to implement a set of markers distributed in the room or in the building and combine them with additional knowledge of the environment. As one can see in Figure 2.6, in order to track objects in an indoor environments, it is important to have a diagram of the geometric model of the space, and at the same time the specific location of the markers, in this case the red dots.
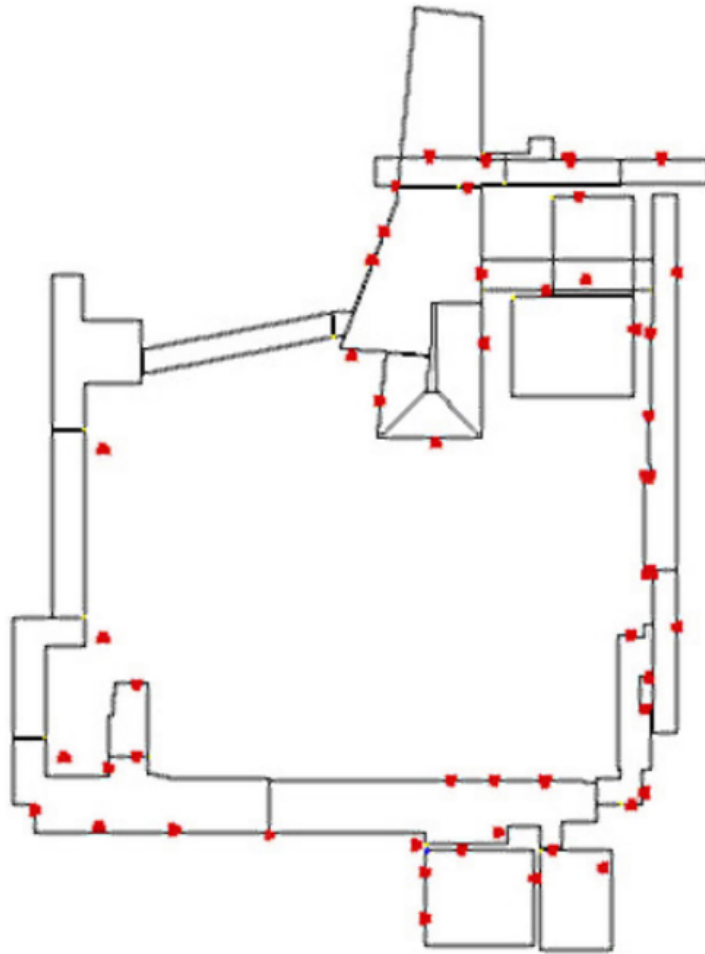
Figure 2.4: Indoor tracking using markers (extracted from [39])

2.1.5   Indoor and Outdoor Tracking Using Augmented Reality

Moreover, another group of researchers [36] has proposed an alternative of a positioning system, both for outdoor and indoor environments, using user's coordinates along with vision angles. The general idea is to use a technique called *Infrared invisible marker identification* and adopt the outside-in tracking mode in order to develop the *Head Marker Tracking Augmented Reality* (HMTAR) system. What is interesting of this study, is that it makes first a comparison in terms of accuracy of the current techniques used for posi-

tioning such as ultrasonic tracking, optical tracking and mechanical tracking amongst others. The main idea of this approach is to use several cameras that will detect a single invisible head marker that can be the user itself providing all the information required to compute the position of the user. The headset allows a multi-marker detection, this kind of detection ensures that at least one side-marker can be detected. The advantage of this approach is that only one marker is needed to do the positioning. In Figure 2.5 one can see the position detection module and a mobile display module.
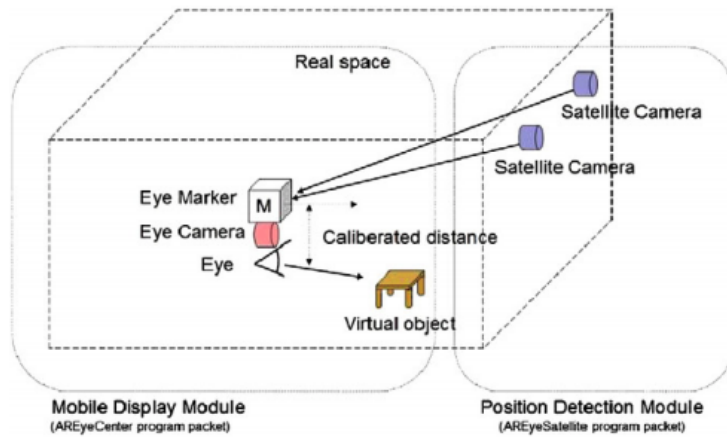
Figure 2.5: Position principle framework. Extracted from [36]

2.2 Tracking Objects and Their Textual Evolution

This is the patent [29] for a system that includes cameras that help with the monitoring of objects and documents marked with a unique identifier, across space and time. This system aims to look at all document movements, using character recognition, as well as where they came from and what has been said about them.

The markers are printed with a special ink, invisible to the human eye, unless it starts fluorescing. The paper used in this invention includes information about the optimal wavelength that causes the marker to emit fluorescent light. All the cameras are equipped with an ultraviolet flash that makes the fluorescent markers, and since the user has the information about the right wavelengths for the markers, they should match; at the same time these cameras have a filter that differentiates the different wavelengths and helps the

system to filter the identifiers.The processing module of this system is used to track objects in different locations; this centre is equipped with a recognition module that identifies each of the markers. In addition, the centre has a recording module to record the location of each object.
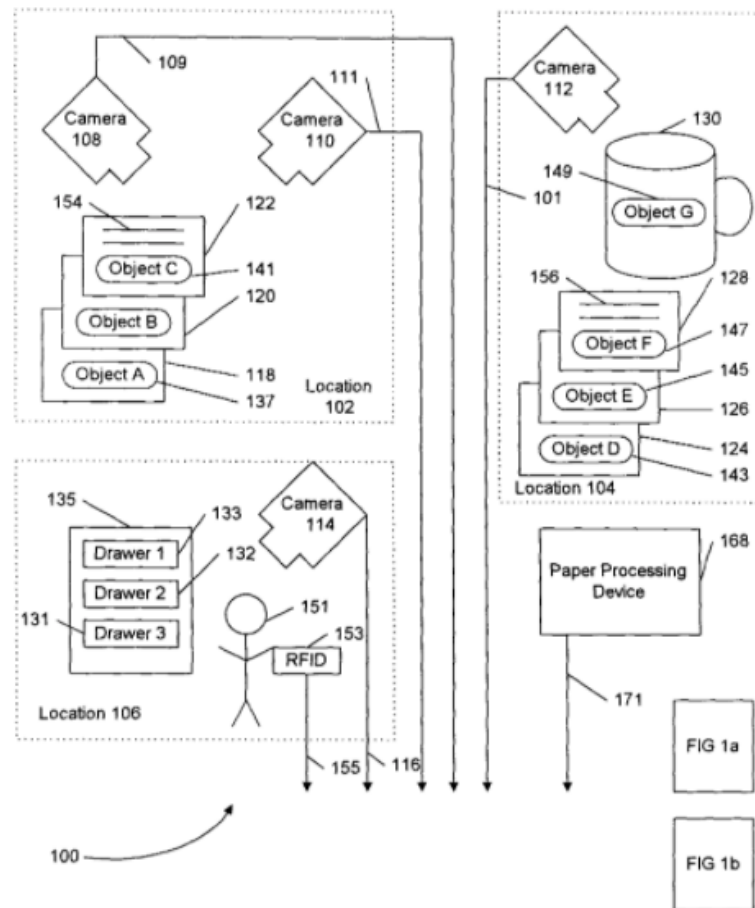

Figure 2.6: Shows the upper part of the system according to this invention. Extracted from [29]

This invention was inspired by trying to find a way in which documents could be managed and located at any time and in any place, without the need to result in an invasive method for the user and respecting their privacy. This system aims to observe all document movements, as well as where they came from and what has been said about them.

2.3 Office of the Future

Given that one of the main objectives of our work is to present technologies related to augmented reality that can be used in the "office of the future", it is important to study what is being done in this field and the perception of other researches about this topic. Moreover, it is also interesting to see this perception in previous decades.

For instance, there is a study [37] published in 1998 by researchers of the University of North Carolina about how they see the office of the future and the technologies that would be suitable. Their approach was to combine computer graphics and computer vision to make projection of graphics and text onto any surface of the office. This could be done by replacing the lights located on the ceiling with projectors that will display the information mentioned above into a surface. To achieve this purpose, it would be necessary to extract the depth of a surface regarding the projector. This approach is really interesting since any surface could be used to project graphics or text which is related to the present work in the sense that a book or document will be used as surface to display any relevant information.

Another related work is the system and method for tracking positions of objects in space. This invention proposes the use of cameras, in a certain space, that monitor the movement of documents through space and time.

Regarding object tracking, a very rudimentary and old method to keep track of physical documents and their digital copy was to attached them together (e.g. attaching a CD to a physical document using a clip or a folder). Of course, this solution presented a lot of disadvantages, because the document and the electronic device could split apart at some moment and, in the worse case, part of the information could be missing.

Over the years new solutions were implemented, for example, adding the location of where a physical document should be located, in a virtual register, similar to the catalogue of products in a big store. However, having the record of the location of a document does not guarantee that it is in that place.

2.4 Existing Software and Tools

2.4.1 Spatial

Spatial [15] is a tool that uses Mixed Reality in a workspace. This tool offers solutions for integrating Virtual Reality, Augmented Reality and Mixed Reality within an office, allowing meeting rooms to be available to users who require them, even when they are not in the building. Spatial has also been

designing immersive audio experiences and at the same time working with Oculus[4] to create a space that represents a virtual office, where everyone can see each other in real time and interact with all the tools that are in place. This solution helps a lot with team planning and onboarding of newcomers, which at some point represents a big investment of money for companies in terms of the logistics they have to consider.

2.4.2 DocTr: A Unifying Framework for Tracking Physical Documents and Organisational Structures

DocTr is a framework based on the analysis of user-centric requirements [40]. Its goal is to simplify the development of interactive computing systems for personal cross-media information management, as well as the unification of existent document management setups and the management of document metadata across organisational structures.

The DocTr framework offers a simple user interface that helps in the exploration of tracked documents. The great advantage of using DocTr is that it is possible to do the tracking of documents across organisational structures, regardless their own tracking setups. Furthermore, this framework allows the tracing of the organisational structures themselves, which is usually not supported for any other framework in the market.

This framework has its user-centric design requirements based on research and interviews conducted by the researches, the five requirements are:

- *Categories of organisational structures:* DocTr integrates the tracking support for the three categories: files, piles and mixtures. One of the outcomes of the interview showed that user usually prefer a semantic description of a document position.

- *Flow of documents and organisational structures:* Another outcome of the interviews showed that usually people are more reluctant to the current tracking technologies, because they usually do not support, or have limited support, for tracking documents across organisational structures. Since the paper documents can contain cold, warm or hot information, implementing a solution that keep track of the flow of organisational structures can offer a unified solution to the user, who would be able to integrate the history of a document and be aware of rarely accessed documents.

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[4]`https://www.oculus.com`

- *Custom metadata:* Users prefer to add their own metadata to the documents. It is important to mention that this metadata can be positional as long as arbitrary annotations, like notes of the contextual information.

- *Integration of third-party applications*: The study showed that users prefer to have their metadata available in third-party applications as well, this gives me more freedom of movement since they can access to the information anytime and anywhere.

- *Integration with a personal information management (PIM) framework:* Even though PIMs have a promising future, the fact that they are mostly supporting only digital documents, can be a problem for users who want to add their own custom metadata to the framework. Therefore, a solution that integrates PIM functionality and the metadata of paper documents, creating a unified cross-media PIM solution will lead to a more united personal information space.

- *Managing unique identifiers:* There is the possibility that different unique identifiers, with a special format, will be assigned to different paper documents based on the tracking solution been implemented at that moment. Therefore, it has to be possible to support multiple unique identifiers for a single paper documents or organisational structure, allowing in this way a proper management of the flow of different items and tracking setups.

DocTr is based on a client-server architecture, where the DocTr server uses the component-based architecture shown in Figure 2.7. Furthermore, DocTr creates a middleware between multiple tracking setups and those third-party applications that want to use the tracked metadata of a document.
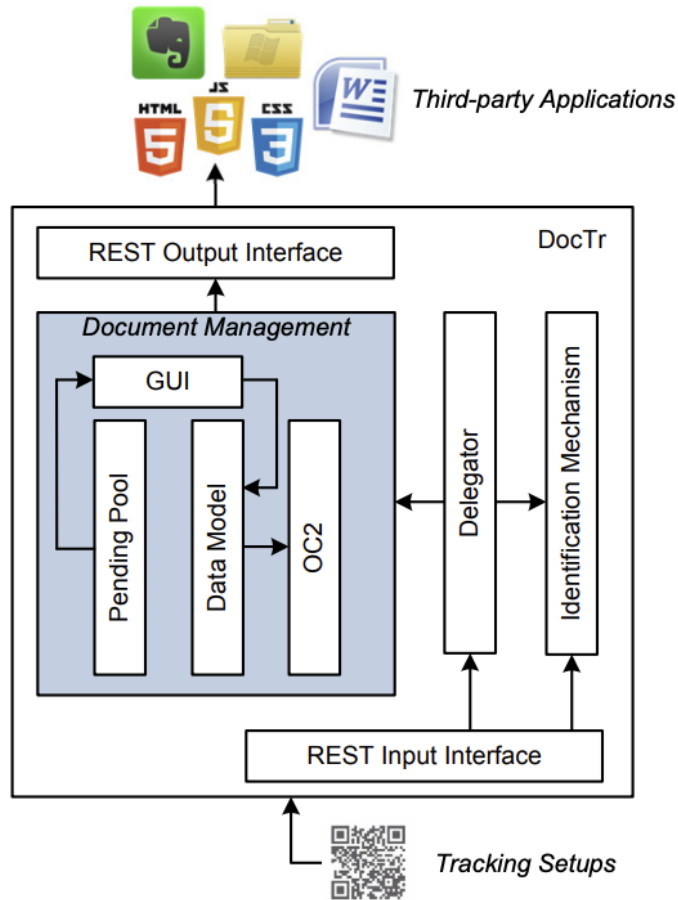
Figure 2.7: DocTr architecture overview (extracted from [40]

DocTr offers two server-side REST interfaces that client applications can use to communicate with DocTr, as shown in Figure 2.7. There is also a distinction between a paper document tracking client application and client applications using the tracking metadata. On the one hand, the *REST Input Interface* helps tracking setups that add information about documents located in the monitored area; on the other hand, the *REST Output Interface* can be use for third-party applications which need to use metadata of organisational structures and tracked physical documents.

2.4.3 Video-based Document Tracking: Unifying Your Physical and Electronic Desktops

The approach of this system is the use of an overhead video camera for tracking paper documents located on a desk, and then linking those documents to their corresponding electronic version [40]. Therefore, this work has two main scenarios, paper tracking and photo sorting.

- *Paper tracking*: The system is capable of tracking the changes in the documents and books located on the desk over time and at the same time build a spatial representation of the structure of the desktop. This also enables remote and virtual access to the desktop, so the user is capable of looking for any kind of document or book remotely. The user can send a query to the system when looking for a physical document, based on appearance, access time or keywords. After capturing the video, the system analyses it and match every physical document with their corresponding virtual copy.

- *Photo sorting*: Sets of digital photographs are printed out and subsequently sorted by the user into piles on the desk. Afterwards, the system can recognise these photographs and infers the structure defined by the user, using the physical arrangement as reference. Finally, the user can assign each structure to a particular folder on the disk.

The algorithm for recognition and tracking of the documents has four steps: event detection, event interpretation, document recognition and updating scene graphs. Figure 2.8 shows an overview of the algorithm.
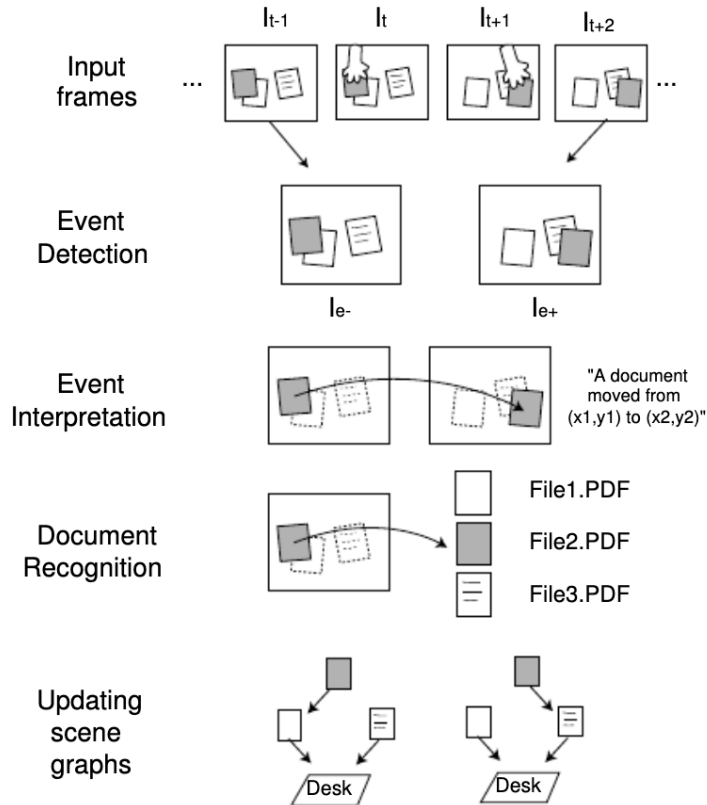
Figure 2.8: Overview of the document recognition and tracking algorithm [35]

- *Event detection*: the movement of a document triggers the beginning of the event and this event lasts until the end of the motion. Differences between consecutive input frames are computed in order to detect an event, when the difference is large, the system assumes that an event is occurring at that time. In Figure 2.8 I_{e-} and I_{e+} represent the frames before and after the event occurs.

- *Event interpretation*: In order to determine the movement and type of the event, I_{e-} and I_{e+} are analysed using the scale invariant feature transform (SIFT). SIFT has three main characteristics: (i) distinctiveness; (ii) invariance to 2D scale, rotation and translation; and (iii) robust matching; which make it reliable in a matching and recognition context. Additionally, SIFT takes the histograms of edge orientation to compute the descriptive local features of an image.

- *Document recognition*: After the event is interpreted, the features of I_{e-} obtained by SIFT, are compared with the features of each of the

digital documents stored in the computer and clustered according to the relative information, generating matching scores, which are the ratio of the sum of matching scores for the features in the cluster. Finally, the matching documented is selected based on the document with the best matching score.

- *Updating scene graphs*: In the first stage of the system, the graph of the scene is empty and new nodes, representing each of the discovered documents, are added. In case the current event is the first event of the document, a new node is added into the complete scene while new edges are created to connect the new node to all the graphs of the scene.

One of the future appliances mentioned for this work in the last part, during the conclusions, was the expansion of this framework to other kind of domains, like bookshelves in a library or a book store.

3
Solution

Before starting with the implementation, it is necessary to define the idea with which we intend to provide a solution to the problem presented in the introduction of this document. It is also important to keep in mind all the concepts, ideas and information presented in the previous chapters, so we will have a better understanding of the proposed solution.
Therefore, the content of this chapter aims to give a better idea of not only the requirements and technologies we want to work with, but also an overview of how we conceptualised and structure the work presented is this thesis.

As previously mentioned, the aim of this work is to provide a solution using augmented reality together with a web application, which allows to facilitate document tracking in an office environment. But why use augmented reality in this context? The reason is simple; nowadays, the amount of information that we handle and gets stored on mobile devices is increasing day by day. Many mobile phones even have the same or greater storage capacity than laptops. Furthermore, it is indisputable that much of our information is still in physical form: contracts, agreements, requirements, legal documents, notes, books and the list goes on.

Taking this into account, a web application that manages and tracks a person's physical information, but at the same time digital information, is

becoming indispensable. Moreover, with the increase of teleworking and the combination of professional and personal information, having an office within our homes, being able to find the physical information we have in the shortest possible time, is becoming more important.

The use of augmented reality in applications has seen an increase in recent years. This technology is being used more and more in different sectors, manufacturing, gaming or tourism. Therefore, many more people are familiar with this concept, especially now that it is not indispensable to have a device like the HoloLens[1] to access applications that use augmented reality, but only to have a mobile device (e.g. a cellphone, with sensors, a camera and a compatible operating system). Using augmented reality to track documents in an office environment can reduce the time people spend looking for them, by guiding people to the exact location the document has been registered in.

Now let us talk about our research questions, raised in the introduction, to explain how we plan to answer them.

__RQ1:__ How could we integrate the benefits of augmented reality and a user friendly web application, in an office environment, in order to track documents and books located in that space, as well as getting an insight into them?

This is our most important contribution, as it is the basis of this work. Firstly, it was decided to use a web application because of its versatility, since it is accessible from any device with Internet access, which means that the scope of our application is not limited to a specific type of operating system. On the other hand, this work is designed taking into account that not all users can be aware of the new technologies on the market. Therefore, our work is focused on the average user, who works in an office and requires their documents, books and information in general to be accessible when required. It is because of this that the application of this work must be user friendly.

Finally, with everything previously stated, the solution presented in this work, is one in which the user is the general focus. The web application has been divided into two types of libraries. The first is one in which the user has a record of the documents, books and other information, in physical format, that the user has in their office. The second library within the application has all the user's information, books and documents in digital format.

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[1]`https://www.microsoft.com/en-gb/hololens`

As a first step, the user must provide the map of their office, paying special attention to the location of the bookshelves. This map can be added to the application using the drawing tool, which is part of the options menu within the website, or by adding the image of the map, stored somewhere on the device. It is important to mention that each location, which is intended for the storage of books, should be marked on the map and have a physical tag, placed in a visible and easily accessible place, which will allow the user to be guided through the office. Subsequently, the user must register all their documents and books that are in physical format in the web application, with the corresponding location where they are store, as well as the books and documents the user has in digital format. This process is shown in Figure 3.2.
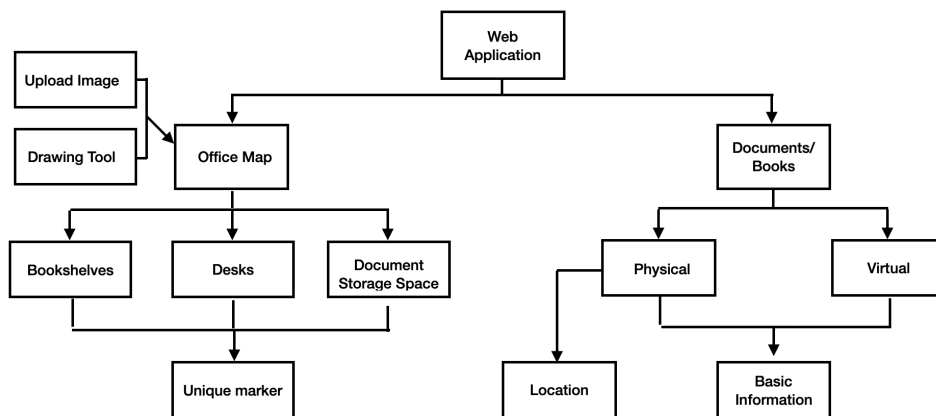
Figure 3.1: Basic approach of the web application
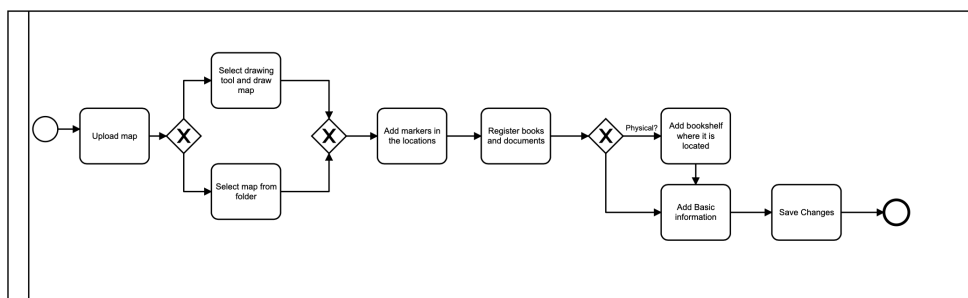
Figure 3.2: BPMN of first interaction with the web application from user's perspective

There are two ways in which the user can use the application for a search, but the general idea is shown in Figure 3.3.

Figure 3.3: General proposal

The first way is by searching for a specific book or document. The user enters the title of the document or book they are looking for, and the application uses it to send a query by title to look for it in the database. At the same time the user has to scan one of the markers located in any of the bookshelves, this way the application can position the user on the map and start with the guiding process. After getting the result of the search, in this case the location, the application guides the user through the office, using augmented reality until the user finds what they were looking for, as illustrated in Figure 3.4.
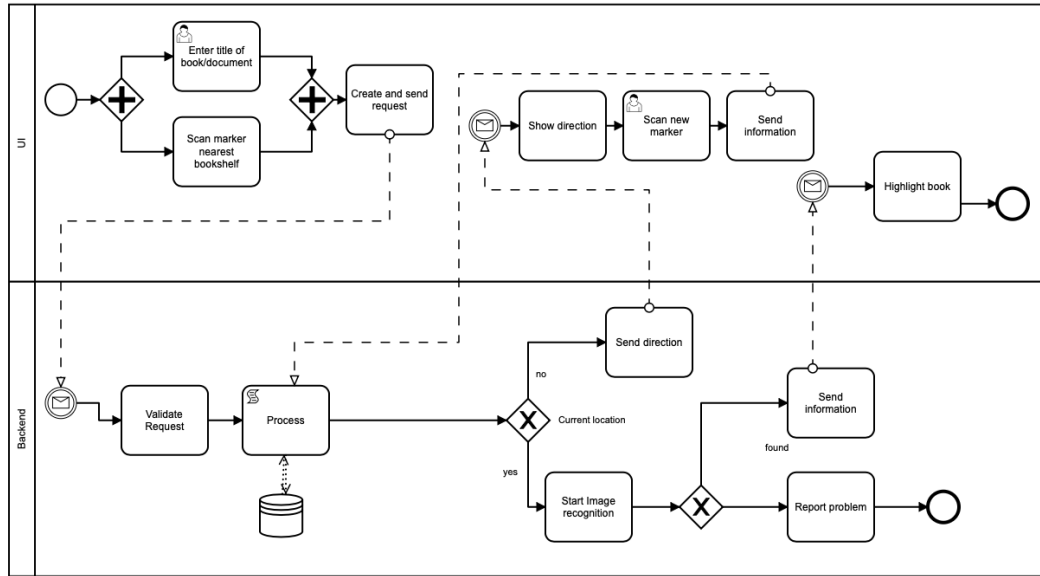
Figure 3.4: BPMN of search for a book, first approach

The second way is by placing the topic about which the user needs to acquire certain information, inside the search panel. The application then creates a search of all the files, documents and books that refer to that topic. The result is a list, according to the relevance to the topic, of all the files, documents and books whose content matches the search. Once the user selects the most suitable result, the application guides the user through the office until the user scans the marker of the place where the item is located. Once the user is in the right location, the application runs an image recognition process, scanning all the books, until it finds the correct one and show it highlighted using augmented reality. A model of this process is shown in Figure 3.5.
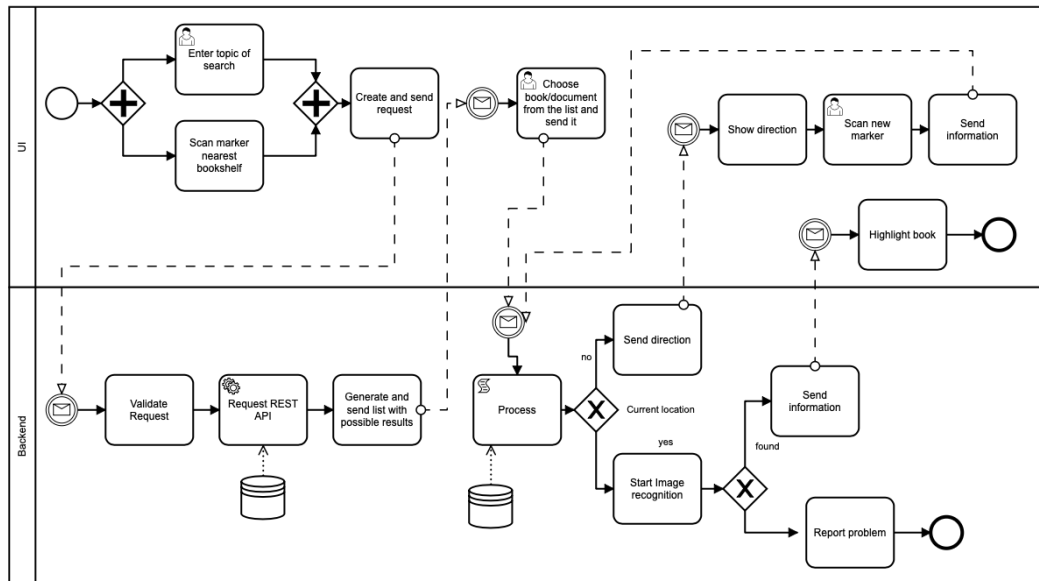
Figure 3.5: BPMN of search for a book, second approach

RQ2: *How could we retrieve information from a book using current APIs that are available in the market?*

In order to access the information and/or summary of a document or book, it is important to have some kind of tool that returns what we are looking for. Asking the user to access all the information, manually of all the documents that they have in their office, requires time and dedication, which we want to avoid with the use of this application. Currently there are APIs that return the information we are looking for just by entering the title or the international standard book number (ISNB) as a search parameter. Once our system obtains the results, the backend does all the analysis to find those books, which were part of the result, that are most relevant to the search topic entered by the user.

RQ3: *What is the best approach for the design of an augmented reality application, taking into account the user preferences?*

For this point, different user interface designs have been taken into account, mainly the view containing the augmented reality signage. As previously mentioned, this work is focused on people whose work is done in an office, regardless of their skills in handling new technologies. The details of the users has to be taken into account as well, as people working in an office

are not limited to a specific age group. Based on the feedback received from the first users, the final version of the user interface has been chosen. On the other hand, a responsive design also has been taken into account, as the devices to be used may vary in terms of size and image resolution, which could generate errors when guiding the user.

RQ4: What are the best tools available in the market nowadays, to implement an easy and user friendly application?

Particularly, for this work, we have to consider the tools that allow us to develop a web application, which at the same time implements augmented reality resources, in order to guide the user through the office and show the location of the documents or books that they is looking for. It is important to make an analysis of all the tools that are compatible to each other in a web environment and select the ones that are the most suitable for the goal of this work.

RQ5: How to implement a solution that allows the location of a specific document within a pile of documents on a desk?

This solution goes beyond the basic approach of this work. When a set of documents are stacked, putting a marker on each element does not allow the desired document to be easily located, as the logic previously used for finding books and documents does not apply in this case, where the location is basically the same for such a group of elements.

As mentioned in the previous chapter, when a general overview of related work was given, one of the solutions is the positioning of cameras that track the movement of documents around the office in a certain time range. While the use of cameras is a possible solution to this problem, the installation of cameras creates a disruption of the environment, with the risk that not all cameras cover the surface of the room, creating blind spots. Another major problem with the use of cameras is the issue of privacy, as they are filming all the time.

After a thorough analysis of this problem, taking into account all the literature reviewed about this problem, it was found that a feasible solution, which does not involve the installation of cameras, is the addition of a LightPaper[2], or similar product, to all documents. When the user needs

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[2]`https://eoslight.com/lightpaper-intro`

to locate a document that is in a pile of items, they first have to locate the place where it is located, when they get to the place the led light belonging to the searched document turns on, and the user can simply remove it from the place, without having to search through each of the documents that are there.

4

Implementation

In this chapter we explain the reasons that led us to choose the tools and frameworks used in the development of this Master's thesis. As explained in the previous chapter, this work aims to create a web application that serves as a personal information management, and at the same time allows us to locate books and/or documents inside the office of the user, using augmented reality.

Thus, we first present the tools that were considered for the development of this work and their subsequent analysis, specifying how the transition from the theoretical to the practical part was. Then we present the design of the application, the interaction with the APIs and the structure of the system. Subsequently, we describe the augmented reality functionalities. In the last part of this chapter, we talk about the challenges encountered during the implementation of this project.

4.1   Augmented Reality Tools Analysis

Nowadays, there are different tools that help us to develop and integrate augmented reality in different types of applications, some of the most popular ones in the current market are listed below:

- *Vuforia* is a software development kit (SDK) used for the creation of augmented reality applications for mobile devices [20]. It recognises and it is able to track images in two-dimensions as well as three-dimensional objects in real time thanks to its computer vision technology. One of the biggest advantages of Vuforia is the versatility it offers to the developer, as it is not limited to a single programming language or operating system. To be able to use the Vuforia SDK, the user has to pay a fee, the basic one costs 504USD per year [19].

- *ARKit* is a framework and software development kit created by Apple[1] [5]. It combines the information generated by the motion sensing hardware of iOS[2] devices (e.g. device motion tracking) with the computer vision analysis and advance scene processing, of the scene captured by the camera of the device, to create a relation between virtual and physical spaces, this technique is called *visual-inertial odometry* [17]. One of the advantages of ARKit is its ability to perceive the environment, making it unnecessary the use of markers for the projection of a virtual element and therefore giving the flexibility of deployment in any type of environment. Another advantage is the estimation of ambient light that is subsequently applied to the generated virtual element in real time, resulting in a mimicry of the virtual element with the environment. ARKit can only be used with Apple devices, which must have at least an A9 processor. Therefore, older Apple and non-Apple devices are not an option for the user.

- *ARCore* is a platform developed by Google, which allows the building of augmented reality applications [4]. With the use of different APIs for developers, the mobile device is able to analyse and detect the surrounding environment through the camera and sensors. Through the camera of the device it identifies points of interest in the environment as well as flat surfaces, then creates an internal map with the information obtained and it is able to implement the element in augmented reality. When the mobile device changes its position, ARCore measures the new distance between the points of interest and thus estimates the location

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[2]https://www.apple.com/ios/ios-14/

of the device at that moment, as well as its orientation. ARCore has three main features that allow the integration of virtual content with the real world: motion tracking, environmental understanding and light estimation. The compatibility with different mobile devices is another of ARCore's advantages, as it supports devices running Android emulator, Android[3] and iOS.

- *WebXR* is a standardised device API, developed by W3C[4] that provides access to capabilities normally associated to virtual and augmented reality [21]. W3C mentions in their documentation that the *X* is not simply part of the acronym, but with this they intend to let the general public know that their API is not limited to just one type of technology (e.g. augmented reality or virtual reality), but to all those that require a standard that allows them to access functional elements in devices. It also allows the developing and hosting of virtual and augmented reality experiences on the web by providing the necessary interfaces that let the direct interaction with immersive hardware. WebXR aims to cover areas that do not necessarily fall within a standard app-store model and give the flexibility to its users and developers to access them via the web, thus everything can be integrated into the same website and any required change can be made individually without affecting the user experience. The main use cases covered by WebXR are: video, object/data visualisation, and artistic experiences. In order to enable augmented reality application on the web, WebXR has to: detect the available XR capabilities, query the XR device capabilities, set the state of the input device, and finally display the content on the XR device with a convenient frame rate. Since WebXR is an API there are parts of it that are not fully covered, for example it can not expose every feature of the virtual and/or augmented reality hardware, nor define how the browser would work while rendering the virtual elements [22].

- *OpenXR*: is an open, royalty-free standard, developed by Kronos Group[5], that let the applications reach a wider variety of hardware platforms and devices for virtual and augmented reality [14]. It provides directly cross-platform, high-performance access to runtimes of XR devices across several platforms, giving the freedom to make content available anywhere, since major players in the industry of augmented and virtual reality (e.g. Google, Microsoft, Mozilla, Facebook and Unity)

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[3]https://www.android.com
[4]https://www.w3.org
[5]https://www.khronos.org

are being part of this group, and eliminating the need for third-party software processes [11]. One of the advantages of OpenXR is the possibility of running XR applications in 5G edge cloud[6], thus the images can stream over a low latency 5G connection and be displayed in the XR device with minimal overhead; at the same time, OpenXR standardises the display composition, and therefore ensures a proper scene render based on the position and orientation of the user [10].

- *A-Frame* is an open-source web entity-component framework for building virtual and augmented reality experiences [1]. It provides a declarative extensible and composable structure to tree.js based on top of HTML using a polyfill for custom elements. Since most of the web was built on top of HTML most of the existing libraries and tools work with A-Frame as well (e.g. Angular[7], Vue.js[8], React[9]) The performance of this framework is optimised for WebXR; it allows A-Frame to use the DOM, while its elements do not touch the browser layout engine. This framework let the three-dimensional object updates be done in memory with little garbage and overheat.
  This framework has an entity-component-system (ECS) architecture, which allows the scalability of applications in terms of complexity and eliminates the problems of long inheritance chains with complex functionality. Furthermore, A-Frame makes ECS declarative and based on the DOM, which means that it can start referencing other entities with query selectors and decoupling cross-entity communication with events, among other abilities.

After having made an analysis of the tools and frameworks for the creation of augmented reality applications, it was decided to use WebXR and A-Frame, the reasons that led to this decision were the following:

- WebXR creates a standard API for different types of devices, so a customisation of our work is not necessary in the future.

- WebXR has no restrictions on operating systems or processors.

- A-Frame is built on top of HTML, so no knowledge of an external language is required.

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[6]`https://www.nokia.com/networks/portfolio/edge-cloud/`
[7]`https://angular.io`
[8]`https://vuejs.org`
[9]`https://reactjs.org`

- WebXR and A-Frame are currently compatible and have a stable integration with each other.

It is also important to mention that the implementation of OpenXR was considered in our project, but due to its release two years ago, there is not much documentation on how to use it or how to integrate it with existing projects. However, it has great advantages such as the possibility of running XR applications in 5G and the directly cross-platform that can help in future projects.

4.2   General Approach

4.2.1   System Requirements

As mentioned in previous chapters, this master thesis is intended as a web application that uses augmented reality resources to locate physical information within an office. This application is intended to be used by any user without the need of installing an application on a mobile device. The development tools must be focused on web applications and information traffic through the Internet.

4.2.2 Architecture

The basic architecture of our application is pretty simple. As shown in Figure 4.1 the web application is locally hosted in our computer and it uses the Google Books API to retrieve the books that the user has registered in the bookshelf created for this purpose. We use Ngrok to create the tunnel that exposes our locally hosted application to the web (the detailed process is explained in the next subsections) and therefore, allow us to use any mobile device to connect to our web application. The application request permissions to the end-user to access to the camera and sensors of their device, so the augmented reality interface can make use of them. The mobile device scans the markers to start the interaction with the augmented reality interface.
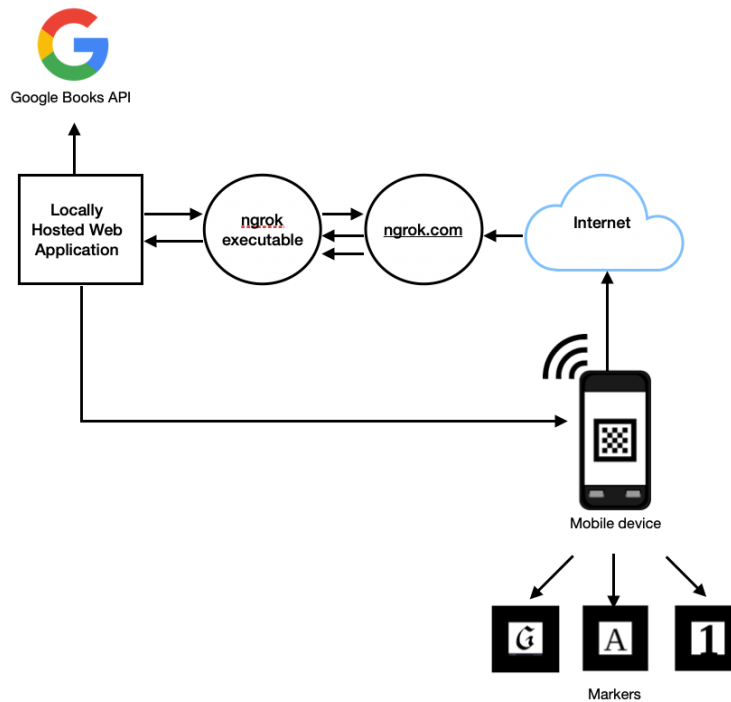
Figure 4.1: Architecture of the application

4.2.3 Angular 9

Angular is an application design framework for developing efficient single-page apps built on TypeScript and with support by the Google team. This framework is based on components, templates and dependency injection and has a model-view-controller architecture. A command-line interface can be set up

in the project, which can be used to initialise, develop and maintain Angular applications through the terminal. One of the most important characteristics of Angular is the component-based architecture, which gives a high quality and hierarchy to the code [24].

4.2.4 Google Books API

When the user accesses the application, they must connect to their google account, as the books are added to one of the google books bookshelves in the account of the user, through the Google books API [7]. By connecting the information directly to google books we can access all the book information without the need for the user to enter it, the only requirement is that the user provides the ISBN code of the book itself. Because this application requires access to the user's private data, to be precise to "My Library" in the Google Books API, the request must be authorised by an authenticated user who has access to the requested information. To perform the authorisation previously mentioned an OAuth 2.0 token is used, this token is individual for each user, it is for this reason that the user must register his google account the first time he accesses the application. On the other hand, our application has an API key, granted by Google, this key identifies the project and allows access to the API.

4.2.5 Connection to the API

Before, we mentioned that we use Google Books API to extract the information regarding to the books, in this section the connection to the API, as well as the parsing of the information is demonstrated. After getting the API key and the OAuth 2.0 credentials through the Google API Console option in Google Developers, it is possible to start using the API to interact with the personal library of the users. Here is the structure of the response when we send the request to retrieve the list of volumes on the personal bookshelf of the user. The highlighted parts are the ones we parse in our application, since they are the most relevant for our case.

Figure 4.2: List the volumes in a bookshelf

4.2.6 Ngrok

Ngrok is a utility that allows the exposure of any locally hosted application over the web through secure tunnels using reverse proxy [12]. The HTTP and/or HTTPS tunnels have hexadecimal names and additionally this tunnels can be protected by a password. It also provides a real-time web user interface that allows the introspection of the HTTP traffic over the tunnels. When the user requests the access to the locally hosted application through the publicly URL, the Ngrok server resolve the URL to the app that needs to tunnel to and then forwards the request to the right tunnel, which connects to the app, the whole process is illustrated in Figure 4.3. Following there is the description of the step by step process. The numbered arrows are also represented in Figure 4.3.

1. The local app is running and it can be accessed through localhost.

2. Ngrok executable initiates a tunnel to the localhost on the port where the app is running.

3. When the tunnel is set up, the web-accessible URL is provided. This URL is a subdomain of ngrok.com.

4. The publicly-accessible URL is shared with the end-user who then hits the locally hosted app.

5. End-user access the web URL on the Internet

6. The request initially passes by the ngrok server, which will resolve the tunnel between the URL and the app.

7. Ngrok forwards the request to the tunnel created in point 2.

8. The request connects to the locally hosted app.
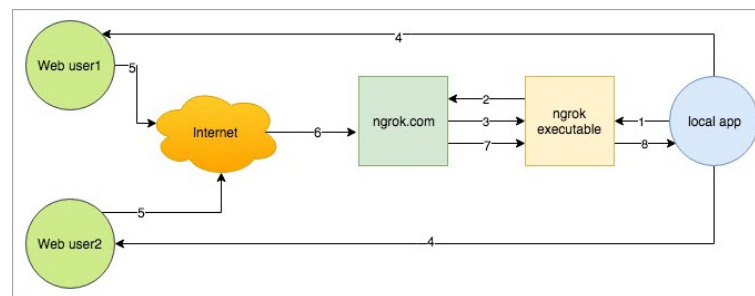
Figure 4.3: Ngrok functionality (extracted from [13])

We used Ngrok in the implementation of our prototype, which let us access to our application hosted locally from any kind of device. We tested our application using four different mobile devices (iPhone 11, iPhone 7 plus, iPad and Samsung A6+). We also used 3 different browsers (Google Chrome, Safari and Mozilla Firefox) and the design was responsive in all cases, and we could use the functionalities without problems, after granting access to the camera and the sensors of each device.

4.2.7   Dijkstra's Algorithm

Conceived and published in the 1950s by Edsger W. Dijkstra, this algorithm is used to find the shortest path between nodes in a graph, using a data structure for storing and querying partials solutions which are sorted based on their distance from the start point. A graph is made of vertices (nodes) connected by edges. These graphs can be undirected (allows loops, since their edges do not have an orientation) or directed (edges have orientation) [34]. In this algorithm, the node at which everything starts at is called the initial node, the distances from every node to the initial node have to be initiated as *infinite*, and they will change step by step when the algorithm is running. There are several steps in this algorithm:

1. All the nodes are mark as unvisited. A set has to be created with all the unvisited nodes.

2. The initial node is set as *current* and its tentative distance as *zero* while the others remain as infinite.

3. Consider all the unvisited neighbours of the current node and compare the new calculated tentative distance. In case the new distance is smaller than the previous one, this has to be updated to the current distance.

4. After visiting all the neighbour nodes of the current node, this is removed from the unvisited set and it will not be visited again.

5. if the destination node is market as visited, or if the smallest tentative distance in the unvisited among the unvisited nodes is still infinite, the algorithm stops.

6. Otherwise, the node with the smallest tentative distance in the unvisited set is selected and market as the new current node.

This algorithm has been considered in some indoor navigation systems, because it allows to find the shortest path between two points, and a localisation system guidance in indoor places can not make use of normal GPS guidance, since satellite signals can cause false information or they can be interrupted by any object in the area [27]. This is the reason why we also decided to implement this algorithm in our application, since we need to guide the guide through the office in order for they to find the requested book. In our prototype, the starting point is always the same, and the location of the book is stored locally within our code. In order to change the location of a book, this has to be replaced directly in the code of our project, this can not be done dynamically.

4.2.8 Augmented Reality Functionalities

As mentioned in Section 4.1 after the analysis of the different augmented reality tools, we decided to implement WebXR and A-Frame in our prototype. Despite the difficulties along the way, in the end we managed to implement an augmented reality interface, which recognises different types of markers and an image appears on the screen to notify the user of the next action to be performed, as shown in Figure A.3

Figure 4.4: Screenshot of the augmented reality part of our interface

As one can see in the figure above, we have decided to use a very simple interface. Even though augmented reality is a technology that continues improving and being more present in the daily life, our application is meant to be used by any kind of user, despite their age of background, which means that it needs to be very easy to use.

4.3 Challenges Encountered

The previous sections made reference to all that was achieved with the implementation of this project, but they do not do justice to all the work that this thesis required from the conceptualisation phase to the implementation. This work required hours of research, testing and re-adaptation in some cases, thus in this section we talk about them, because in the end those challenges are the reason why our final application is what it is.

One of the crucial parts, and the one that ultimately took the most time, was the integration of our web application with the augmented reality tools. First of all, our knowledge about augmented reality was quite limited and simply theoretical, so it was a process of self-learning about this topic to be able to do the analysis of the tools we found and to be able to select the one that best suited our needs. As we wanted our application to be accessible through any web browser and any type of device, we had to take into account a responsive interface design. This type of interfaces require a lot of considerations, but we also had to take into account that it had to adapt to the augmented reality functionalities, which made its creation and design even more complicated, this is the reason why we decided to implement an interface that is simple but at the same time provides all the interactions with the user.

While it is true that after doing our analysis of the most popular augmented reality tools, we decided to use WebXR along with A-Frame for the advantages they offer, and mainly because they are not restricted to operating systems and are compatible with each other, after starting to implement these tools in our code, we realised that we were getting compatibility errors in terms of versions. Unfortunately, WebXR is still in its early years, so the documentation we have is still very limited and the developer community is still not very large, which makes it difficult to find solutions to some implementation problems.

Another problem we found when testing our prototype was the access to the IP of our application using our mobile device. We wanted to use the mobile device to test the prototype, since it is the easiest way for the user to scan the markers and at the same time move around their office, but in order to use the camera and the phone's sensors we must grant the corresponding permissions, which is not possible to do with just an http connection. We try to use GitHub pages, as it is one of the recommended options, especially

if the project is in one of the GitHub[10] repositories. However, in order to use it, it is important that the first view of the application is the index.html file, which is not the case in our application. Finally we were able to solve this problem with the implementation of Ngrok.

Furthermore, due to lack of time, our prototype does not include a database connection, so the information of the books is directly acquired through the Google Books API, and the location of each book is written in the code.

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[10]`https://github.com`

5

Use Case and Demonstration

The first part of this chapter explains all the use cases that a users has access to. In the second section we have a tour throughout our prototype in order to demonstrate its functionalities.

5.1 Use Case

Name	Looking for a book
Summary	The user is working at home and they need to find some information about the British and American suppression of Caribbean piracy, they can recall that some time ago they read something about that topic in one of the books they have, and they can remember the title of the book. Thus, they enter to their library application and start a search based on topic. The result of the search is displayed on the screen, the user selects the book they are interested in and confirm that it is the book they have been looking for, so they start the search around the office. The first step is to scan one of the markers, because the application needs this information to start guiding the user. After getting all the indication, and following them around the office, the user finally finds the book in the bookshelf.
Preconditions	- The user has linked their Google account with the application. - The user has recorded each of the books they own within the office, as well as the location of the books. - The user has at least one book related to the topic searched.
Postconditions	The user finds the book they have been looking for.
Error situations	- The request gives zero results, a book related to that topic cannot be found. - The location of the book has changed but the new location has not been updated.
System state in the event of an error	The book can not be found, the system gives an alert and goes back to the general book list.
Actors	User

Standard process	1) User enters the application. 2) User enters the keywords of the book they want to find in the search field. 3) User selects the type of search they want to perform (title-based, category-based, topic-based). 4) User selects the book they want to look for in the office from the list retrieved by the application. 5) User scans a marker in one of the bookshelves to trigger the guidance system. 6) User finds the book.
Alternative processes	3') There are no books matching the search criteria 4') User enters a new search criteria 6") The book has changed locations, but the new location has not been updated
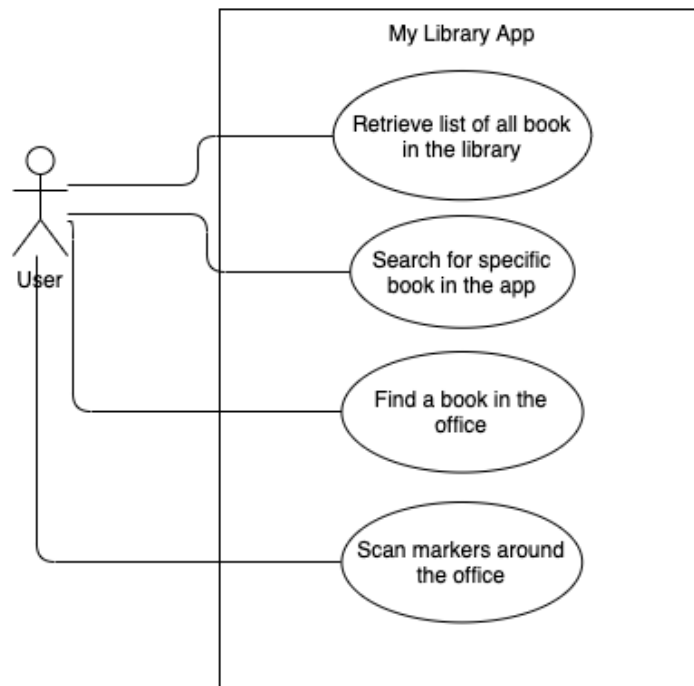
Figure 5.1: Use Case

5.2   Prototype Walkthrough

5.2.1   Access to our Application

As shown in Figure 5.2, the user can connect to our web application through the url assigned by Ngrok.
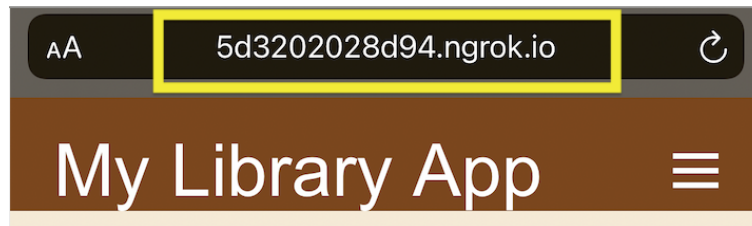
Figure 5.2: Connection to the web application

5.2.2 Searching a Book

In the first view the user has a list of all the books stored in their personal library, as shown in Figure 5.3.
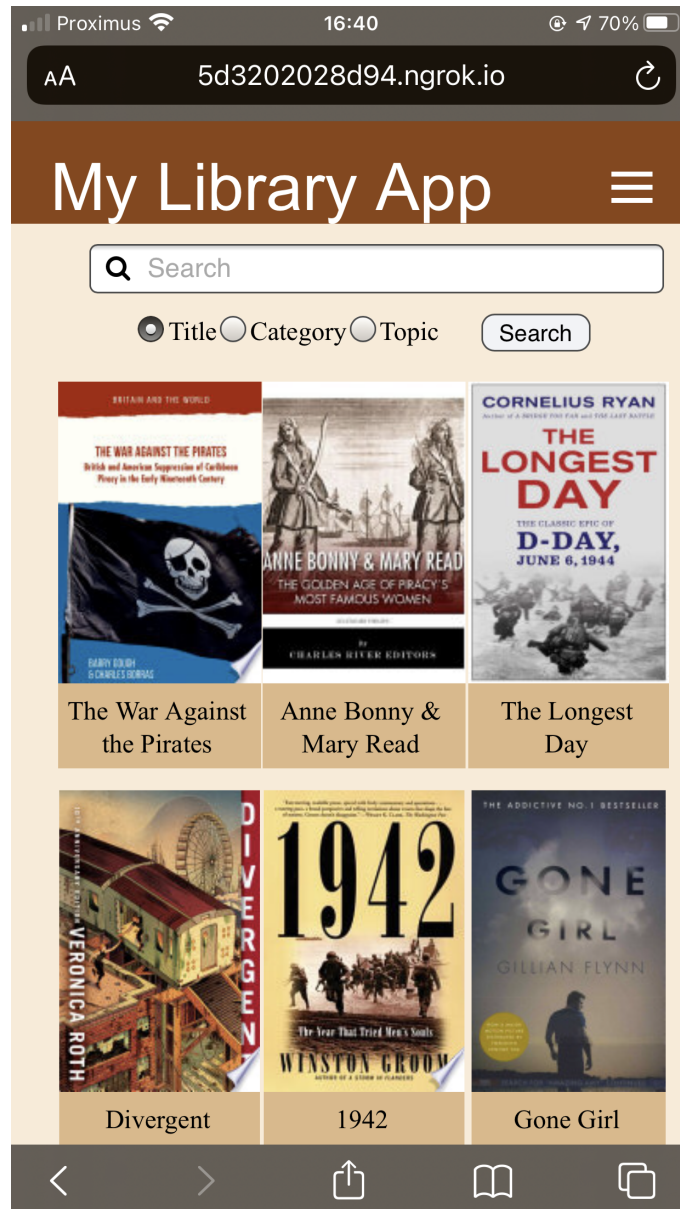
Figure 5.3: User's books list

The user can either select a book, see its details and look for it in the office, or search for a book in their library based on the title, category or

topic. In this section we will show the result when the user performs a search based on topics. In Figure 5.4 the user types the keyword in the search field and selects the type of search they want to perform. The results of the request are shown in Figure 5.5.
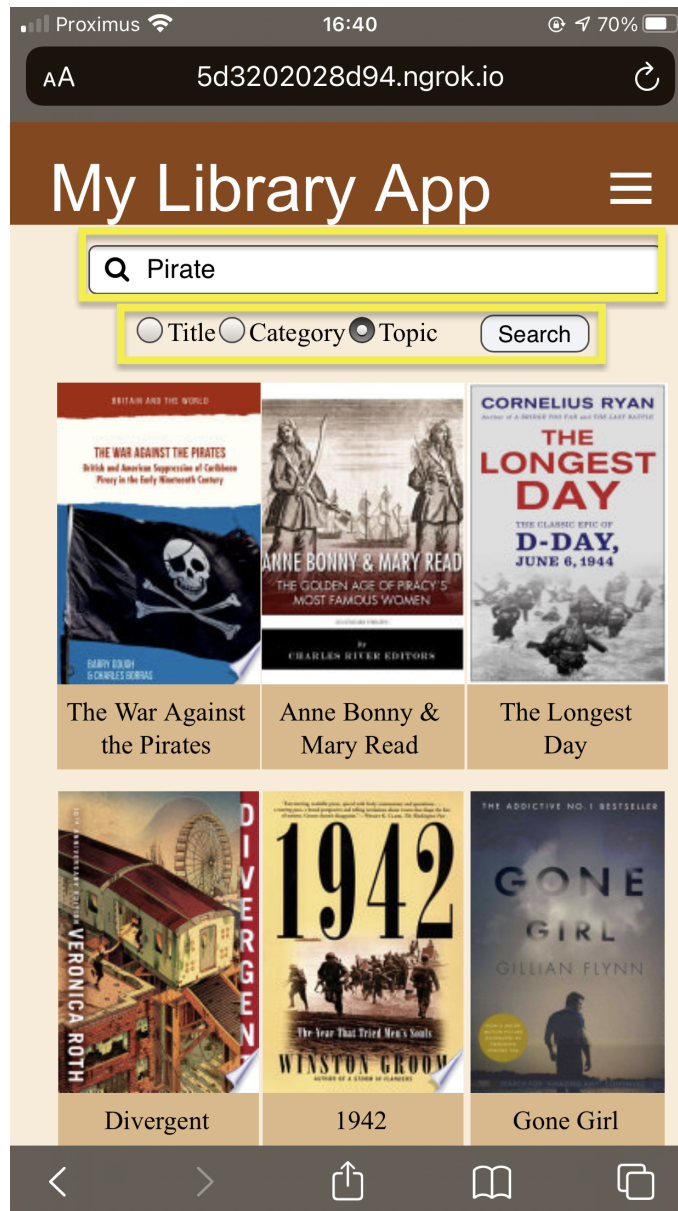
Figure 5.4: Performing a search
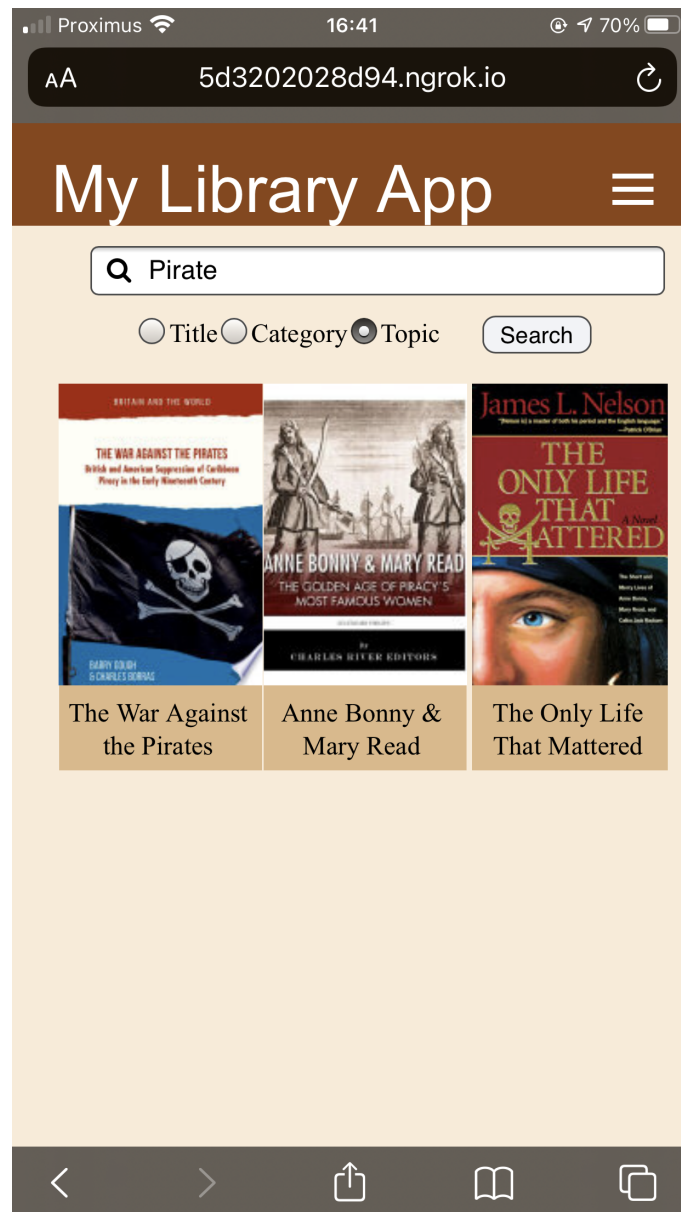
Figure 5.5: Search results

The user can select one of the books in the list to see the details of it or to look for it in the office. The view after clicking on one op the options is shown in Figure 5.6. The button to find that book in the office is located at the right bottom of this view.
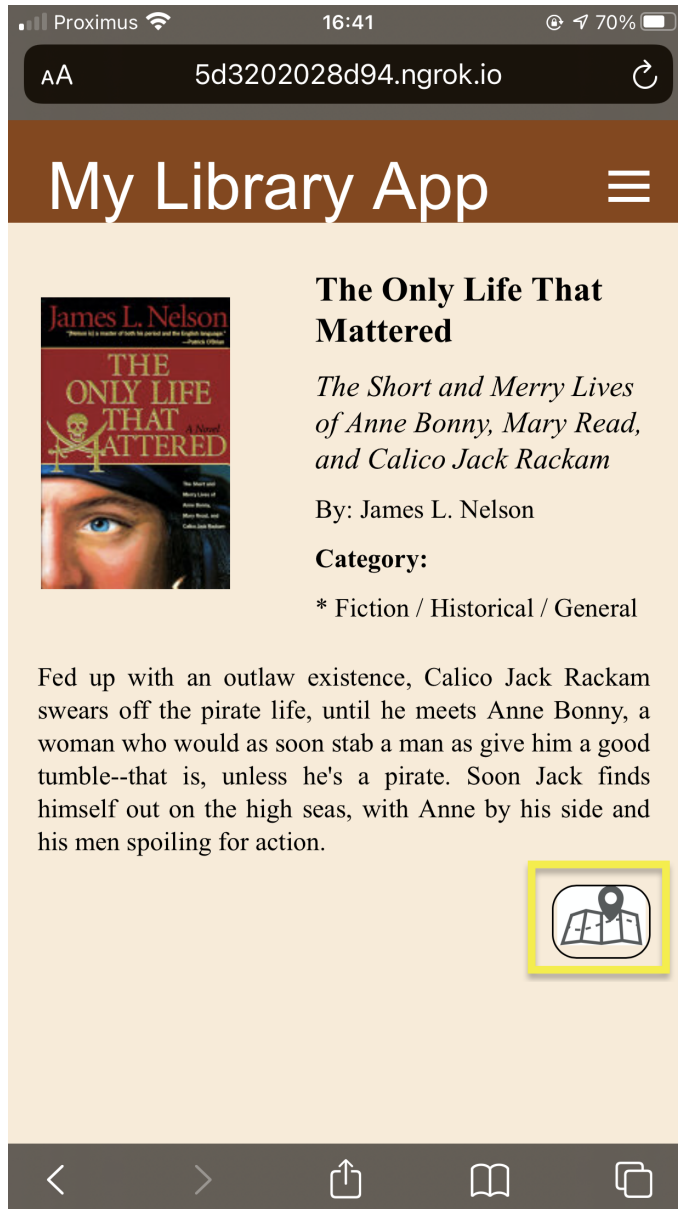
Figure 5.6: Book details

5.2.3   Finding a Book in the Office

In case the user wants to find the book in the office, after clicking the button
in the details view, they have to give the permissions to access the camera
(Figure 5.7) and the device motion sensors (Figure 5.8) to the application.

Figure 5.7: Camera access permission request
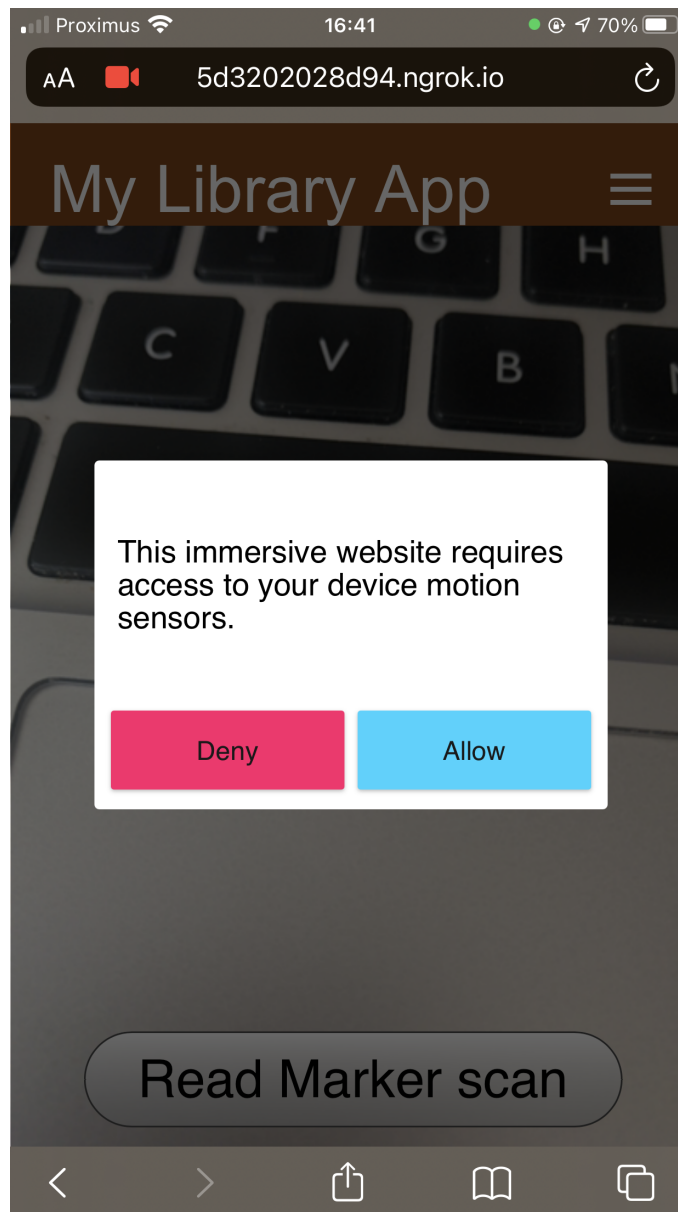
Figure 5.8: Device motion sensors access permission request

Finally, the user is guided throughout the office until they find the book they are looking for.
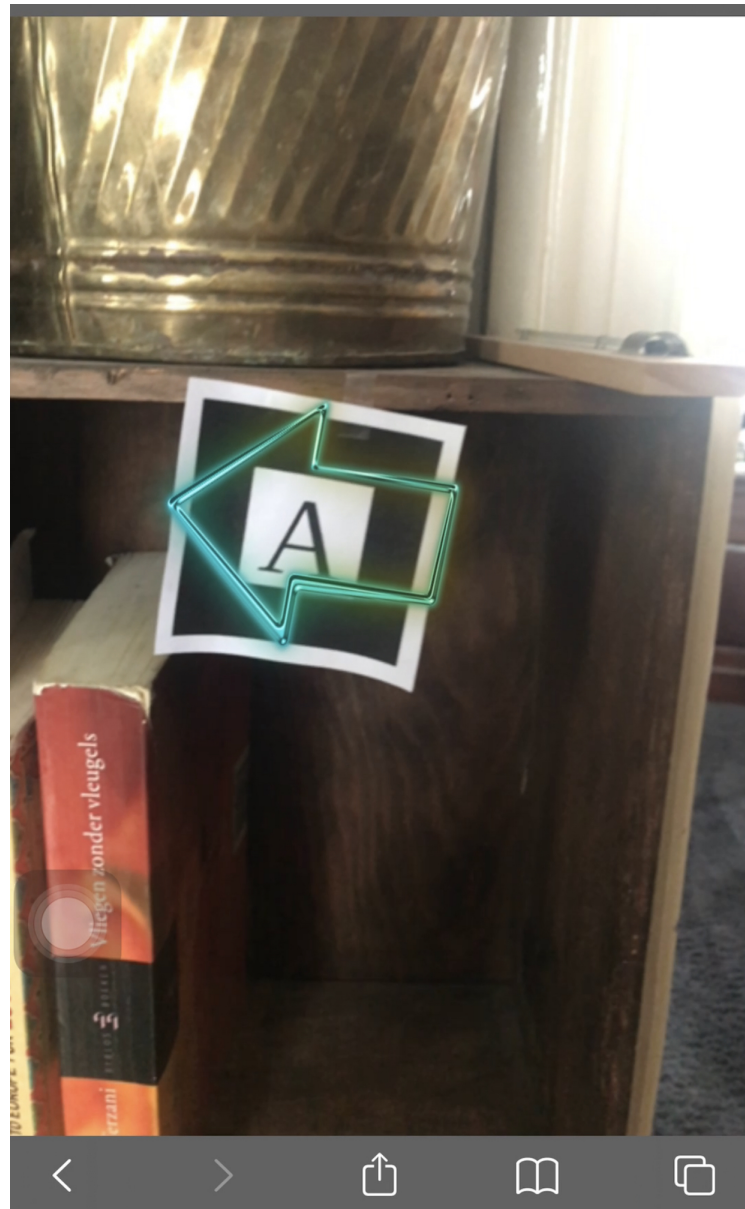
Figure 5.9: Dynamic arrows in augmented reality
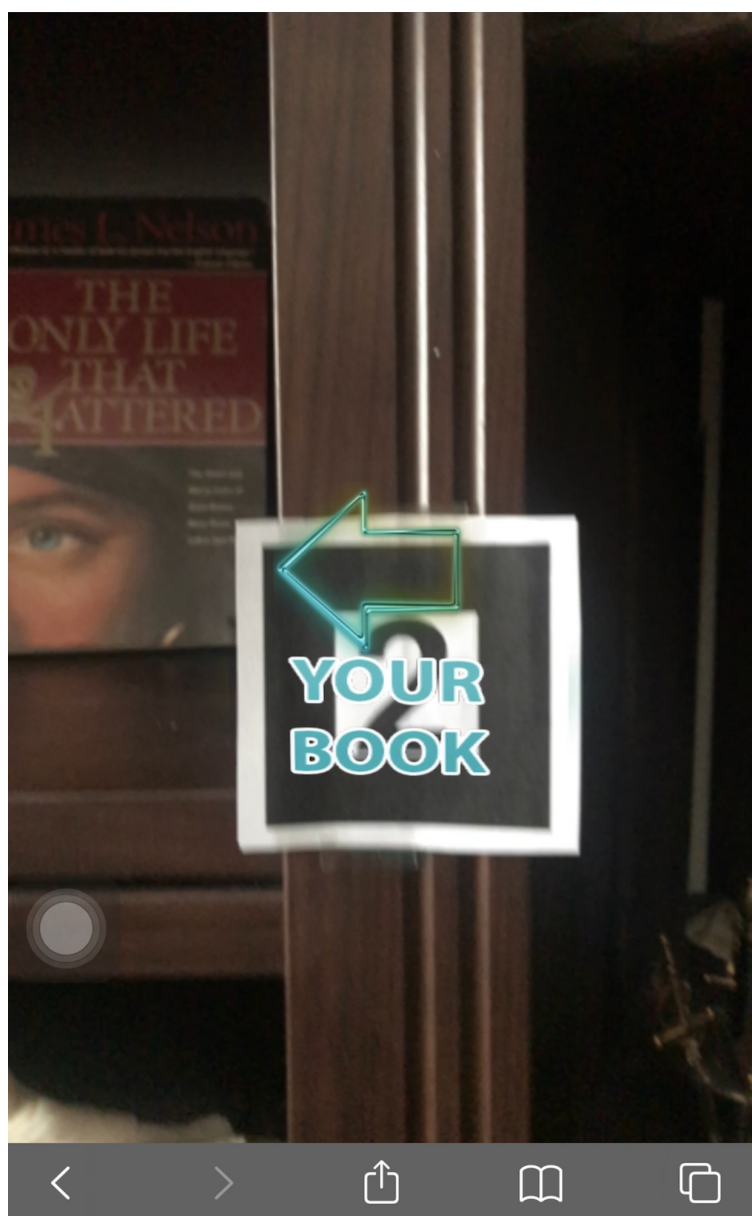
Figure 5.10: Message displayed when the book has been found

6

Evaluation

Throughout the previous chapters, we have explained the idea and the motivations that led us to choose this topic for our Master's thesis, as well as the development of our prototype, as a proof of concept that an augmented reality application can be useful for a user who performs his duties in an office and who also requires books to carry out his tasks. A good practice to measure end-user satisfaction is through the *User Experience Questionnaire* provided by Martin Schrepp [16].

This questionnaire measures the observations and reactions of the user while using a website, application or product, by quantifying the classical usability aspects (e.g. efficiency and dependability) and user experience aspects (e.g. attractiveness, stimulation and novelty). The user experience questionnaire has 26 items that are scored on a 7-point scale, and it has to be filled in right after using the product or application. The end result of the questionnaire is six properties (attractiveness, perspicuity, efficiency, dependability, stimulation and novelty) with a score that goes between excellent and mean [18].

Unfortunately, the current COVID-19 crisis did not allow us to carry out this type of evaluation, but we found a solution to perform a small evaluation and have some feedback from different users.

6.1 Used Questionnaire

We recorded five videos with different options for the augmented reality experience part (text, arrows, glow, animated arrows, and gamified neon arrows) and added them to a questionnaire with 22 questions divided in three sections: evaluating the idea and use of augmented reality, user experience, and the final question. This questionnaire was filled out by a total of 66 people. Since user experience can vary according to several factors, one of them being the cultural difference, we wanted to see if this was a decisive factor in terms of the use of augmented reality and how familiar people are with this technology. It is for this reason that half of our target group are people living in Belgium and the other half are people living in South America, more specifically in Bolivia. The questionnaire had to be written in English and Spanish. It is mainly focused on the first impression of the user about: likeliness, feedback, user-friendliness and the use case.

Here is the list of questions that the participants of the survey were asked:

1. Based on the description, how useful would you rate such an application?

2. Do you still currently use books in your home or work environment?

3. Are you familiar with Augmented Reality (AR)?

4. Do you currently have AR-based apps on your phone or other devices? (Pokémon GO, IKEA, ...)

5. Video 1: User friendly & clear

6. Video 1: Appealing & fun

7. Video 2: User friendly & clear

8. Video 2: Appealing & fun

9. Video 3: User friendly & clear

10. Video 3: Appealing & fun

11. Video 4: User friendly & clear

12. Video 4: Appealing & fun

13. Video 5: User friendly & clear

14. Video 5: Appealing & fun

15. Of the 5 videos, which style do you prefer most?

16. Which type of indication do you prefer

17. Would you prefer this type of application to be very neutral/professional or gamified?

18. Would you prefer this tool to be an application or web-based tool?

19. When you find a book with the app, which of the below would you appreciate?

20. Do you have any general feedback on the approach of this application and videos?

21. Would you use this concept (search tool with guidance through AR) for other purposes than finding books, and if yes, which ones?

22. What is your age range?

It is very apparent that questions 1 and 2 target the idea proposed in this Master's thesis. Questions 3 and 4 are asking about the general knowledge of the participant about augmented reality. From the 5th to the 14th question the main target is the easiness and the likeness of each one of the videos. Question 15, 16, 17, 18, and 19 are about the preferences of the participant. The 20th and 21st questions ask for the feedback of the user, these are two open fields for the participant to write down their thoughts about the prototype and the approach of the application. Finally, the 22nd question is about the age range of the participant, this question allows us to group the answers based on age and have an analysis based on that. The complete questionnaire and its structure can be found in Appendix A.

6.2   Test Results and Interpretation

- *Evaluating the idea and use of augmented reality*: The results of the questionnaire can be found in Appendix A. They show that 43.8% of the participants in Belgium find the idea of our application useful and 31.3% find it somewhat useful. The results also show that the participants sometimes use books in the work environment (30.3%), although the average of participants that rarely use them (24.2%) and the average of participants that regularly use them (27.3%) are very close. About the questions related to augmented reality, on average most of the participants know the technology and currently have one

application on their devices. On the other hand, the results of the participants who live in Bolivia show that in average they find the application useful (36.4%), follow by the participants who find it very useful (30.3%). The results also show that they sometimes use books in the work environment (39.4%) and they know about augmented reality (45.5%), but almost half of the participants do not have any application of augmented reality on their mobile devices.

- *Likeness*: The Belgian participants prefer video 4 and 5, which have animated arrows as part of the augmented reality (27.3%), followed by video 2 (24.2%) with simple arrows. Bolivian participants liked the 4th video the most (46.9%) which has animated arrows, followed by video 2 (21.9%).

- *Interface*: Regarding the general preferences about the interface, Belgian participants are more inclined to choose a more neutral (plain colours, to-the point) application (60.6%), with arrows as part of the guidance system and with a short vibration when they book is found (72.7%). They also prefer to install such application (84.8%) instead of accessing it via URL. Bolivian participants have a preference for gamified (63.6%) arrows (42.4%) in their application. But just like Belgian participants, they are more inclined to install such application in their devices (90.9%) and a short vibration of the device (72.7%), as soon as the book is found.

- *Feedback*: In general the feedback was positive, the idea was clear for most of the participants. They also mentioned that this application has a greater impact when used in large spaces, such as (stadiums, warehouses, libraries ans supermarkets, offices in large companies), or to find other items around the house (keys, seasonal decoration).

The majority of the participants in this questionnaire are between 20 and 29 years old (57.6% for Belgian participants and 75.8% for Bolivian participants), follow by participants between 30 and 39 years old (30.3% for Belgian participants) and older than 60 years (12.1% for Bolivian participants).

7
Future Work

Even though we put all our effort in this work and the prototype of our application, we also know that everything can always be improved, that is why in this chapter we make some suggestions for future work in this field.

7.1 Uploading a Map Implementation

As explained in previous chapters, as part of the proposed solution to satisfy our research questions, uploading a map of the office, or the place where we store our books and documents, is an important part in our idea, since it gives freedom to the user to change the location of the bookshelves and storing places without so many complications and in a user-friendly way. There are several tools that let the user upload an image and start working with it as a map. It can be possible as well, the implementation of a toll that let the user make a draw in real time of the office space and after confirmation star using it as a map. Since this is a prototype and we faced so many issues with the augmented reality we decided not too invest a lot of time in this area, but it can be an interesting contribution for future work.

7.2 Application Maintainability

An important improvement in our prototype is the refactoring of the code and working on its documentation. Currently some of the code is commented, and although the code is understandable, a good practice is to have a detailed documentation of the code so that anyone who sees it can understand it without problems. It is also important to be able to add a style guide to keep making sure that the application has exactly the same style in each of the views. Finally, unit tests must be added to our application. Being a prototype we did not create any unit tests for our code, due to the large amount of changes we had to make during the implementation. However, we are aware of the great advantage of adding tests to any kind of application.

7.3 Improve Augmented Reality Interface

In Chapter 4 we mentioned that one of the biggest problems we encountered when developing our prototype was the integration with augmented reality and getting everything to work as we had planned, so our implementation is quite basic. Therefore, one area for improvement is definitely the augmented reality interface. In a future work we suggest the use of other augmented reality tools due to all the problems we had with WebXR and A-Frame, unless the documentation of these tools and/or the community supporting them increases, as we still believe these tools have a lot to offer to developers. Another option for the augmented reality part could be the use of Google glasses or similar products.

7.4 Implement Searching a Document in a Pile

As part of the solution we proposed for this work, being able to find a specific document in a stack of documents is a great functionality that can be given to this project. Additionally, after analysing the answers obtained in our questionnaire, we could see that this is something that the participants would really appreciate in an application with these characteristics, as it was mentioned several times in the feedback part. The implementation of LED lights is a good alternative for the localisation of this kind of documents because of the versatility it represents, but future research should be done in this area.

7.5   Take Care of Unfinished Functionalities

The augmented reality part and the application part are currently in two different projects, since the integration could not be done because of incompatibility issues. Even though this might sound simple and very straightforward, we could not find a way to solve the constant errors we got, so the future developer needs to have more knowledge about the augmented reality tools we used and how they work internally.

Furthermore, a database has to be implemented, where the books and their location can be stored and edited upon request. Finally, an interface to add books in the bookshelf of Google from our application has to be implemented as well.

8

Conclusion

The main objective of this Master's thesis is the creation of a user-friendly web application that also integrates the benefits of augmented reality for the location of books and documents in an office. With the development of our prototype and after receiving feedback from end users through our questionnaire, we believe that we successfully achieved this goal, as we created an application that displays augmented reality elements that guide the user when they need to find a specific book.

On the other hand, using the Google Books API, we were able to obtain all the information about a book, just by entering the ISBN code of the book.

After analysing the participants' answers obtained through our questionnaire, we were able to implement in the prototype the version they preferred and with which they had a better user experience. At the same time it led us to consider improvements in terms of colour and interface design.

We were able to make an analysis of the most popular tools on the market for the development of augmented reality applications and we had the opportunity to work with some of them. However, we were also able to experience the difficulties of implementing a tool that has a lot to offer but does not yet have the necessary documentation that contemplates different use cases and integration with other languages. Therefore, we concluded that the best option is to use a tool that has a large community to support it, even if the learning curve may seem more complicated.

Finally, this thesis has taught me many important things that can be applied in my future professional life. First of all I learned how to carry out large research work. I also learned that many times challenges present themselves when you least expect them and we must learn to adapt easily to the circumstances. I am very grateful that I was able to do my thesis at the VUB, as learning to ask for help when needed was one of the biggest lessons I learned, and my promotor was always available when I needed it, or even offered his support without me having to ask for it. Despite the global crisis and personal problems that arose along the way, I learned that in the end everything ends and we have to find the strength to keep going, to overcome new challenges, as they always leave us with a lesson and satisfaction of a new achievement completed at the end, and in this case it was the completion of this thesis.

A

Appendix

A.1 User feedback survey

Welcome and thank you for helping with this project!

My thesis focusses on the Office of the future and aims to create a web-based application to help you find books and documents in your home or office environment, through your phone!

Purpose of the questionnaire: The application that I am developing would enable you to use augmented reality (AR), allowing you to look through your phone and be guided to the location of any book or documents in your workspace. Following a search for your preferred book(s) on the app, it will determine its location in your home or office and guide you to it based on markers in your surroundings, telling you when you found the right bookshelf or to go left, right, down or up.

Just imagine that you're working at home and you need to look for information about pirates, are you aware of all the books that you have at home that have references to that topic? Do you know where are they located? with this application you just have to introduce the topic of your search and it will show you the list of all the books you have that mention

pirates. Then you can select one and immediately the camera of your mobile device will be open waiting for you to scan one of the markers in the room and start guiding you around until you find the book you've been looking for.

In the context of this idea and the prototype I am developing it would be extremely helpful to receive some external feedback on the idea and your preferred experience as an end-user.

This will only take 10 minutes and contains 5 short demonstration videos.

1. Based on the description, how useful would you rate such an application?

   ❍ Useless
   ❍ Limited use
   ❍ Somewhat useful
   ❍ Useful
   ❍ Very Useful

2. Do you still currently use books in your home or work environment

   ❍ Never
   ❍ Rarely
   ❍ Sometimes
   ❍ Regularly
   ❍ All the time

3. Are you familiar with Augmented Reality (AR)?

   ❍ Never heard about it
   ❍ I recognise the word
   ❍ I know what it is
   ❍ I use it sometimes
   ❍ I regularly use AR-based apps

4. Do you currently have AR-based apps on your phone or other devices? (Pokémon GO, IKEA, . . .)

    ❍ I don't know

    ❍ No, zero

    ❍ Yes, one

    ❍ Yes, two

    ❍ Yes, more than two

5. Video 1[1]

    • User friendly & clear
    low ◯ ◯ ◯ ◯ ◯ high

    • Appealing & fun
    low ◯ ◯ ◯ ◯ ◯ high

6. Video 2[2]

    • User friendly & clear
    low ◯ ◯ ◯ ◯ ◯ high

    • Appealing & fun
    low ◯ ◯ ◯ ◯ ◯ high

7. Video 3[3]

    • User friendly & clear
    low ◯ ◯ ◯ ◯ ◯ high

    • Appealing & fun
    low ◯ ◯ ◯ ◯ ◯ high

---

[1] https://youtu.be/1rnp2MQ_254
[2] https://youtu.be/Dtp5TSel6TA
[3] https://youtu.be/EHvDgBodHhg

8. Video 4[4]

   - User friendly & clear
     low ○ ○ ○ ○ ○ high

   - Appealing & fun
     low ○ ○ ○ ○ ○ high

9. Video 5[5]

   - User friendly & clear
     low ○ ○ ○ ○ ○ high

   - Appealing & fun
     low ○ ○ ○ ○ ○ high

10. Of the 5 videos, which style do you prefer most?

    ❍ Video 1
    ❍ Video 2
    ❍ Video 3
    ❍ Video 4
    ❍ Video 5

11. Which type of indication do you prefer

    ❍ Words
    ❍ Arrows
    ❍ Moving/animated arrows

12. Would you prefer this type of application to be very neutral/professional or gamified?

    ❍ Neutral (plain colours, clean, to-the-point, basic, only essential elements)
    ❍ Gamified (like a game, colourful, animations, rewarding sound/visuals)

---

[4]`https://youtu.be/Q2owUgGW-tU`
[5]`https://youtu.be/JkuUixbUkSs`

13. Would you prefer this tool to be an application or web-based tool?

    ❍ Application: download & install
    ❍ Web-based: go to a website to use

14. When you find a book with the app, which of the below would you appreciate?

    ❍ Phone vibrates shortly
    ❍ Phone makes a noise
    ❍ Screen flashes

15. Do you have any general feedback on the approach of this application and videos?

16. Would you use this concept (search tool with guidance through AR) for other purposes than finding books, and if yes, which ones?

17. What is your age range?

    ❍ < 20 years old
    ❍ Between 20 and 29 years old
    ❍ Between 30 and 39 years old
    ❍ Between 40 and 49 years old
    ❍ Between 50 and 59 years old
    ❍ > 60 years old

A.2 Answers Survey in English

Based on the description, how useful would you rate such an application?

32 respuestas
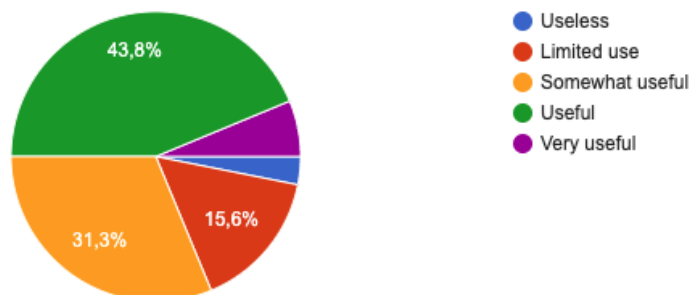
Do you still currently use books in your home or work environment?

33 respuestas

- Never
- Rarely
- Sometimes
- Regurlarly
- All the time

27,3%

30,3%

12,1%

24,2%
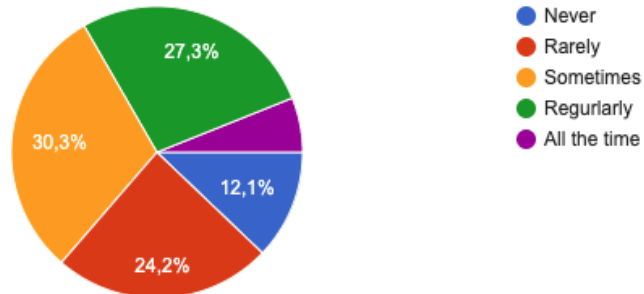
Are you familiar with Augmented Reality (AR)?

33 respuestas
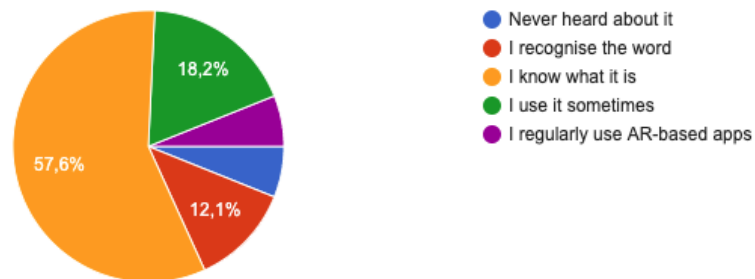
- Never heard about it
- I recognise the word
- I know what it is
- I use it sometimes
- I regularly use AR-based apps

18,2%

57,6%

12,1%

Do you currently have AR-based apps on your phone or other devices? (Pokémon GO, IKEA, ...)

33 respuestas

- I don't know
- no, zero
- yes, one
- yes, two
- yes, more than two

15,2%

39,4%

33,3%
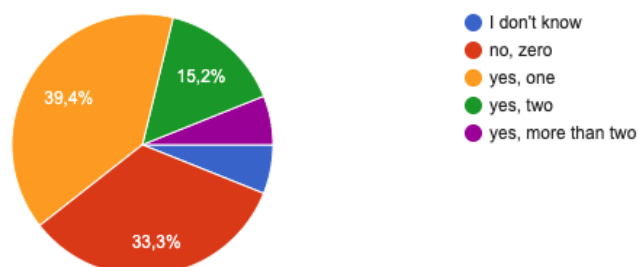
User friendly & clear
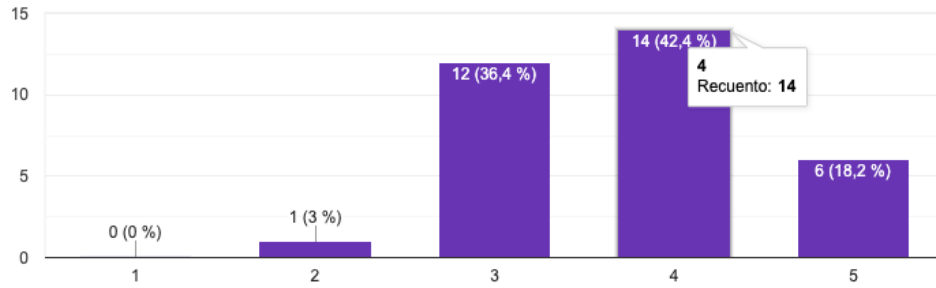
33 respuestas

Figure A.1: User friendly & clear Video 1

Appealing & fun

33 respuestas
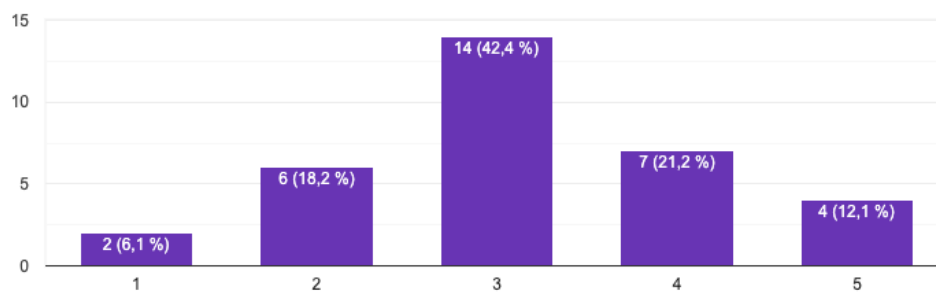
Figure A.2: Appealing & fun Video 1

User friendly & clear
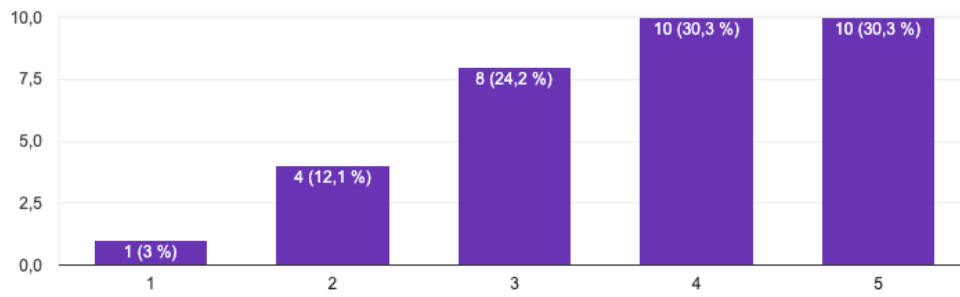
33 respuestas

Figure A.3: User friendly & clear Video 2

Appealing & fun

33 respuestas
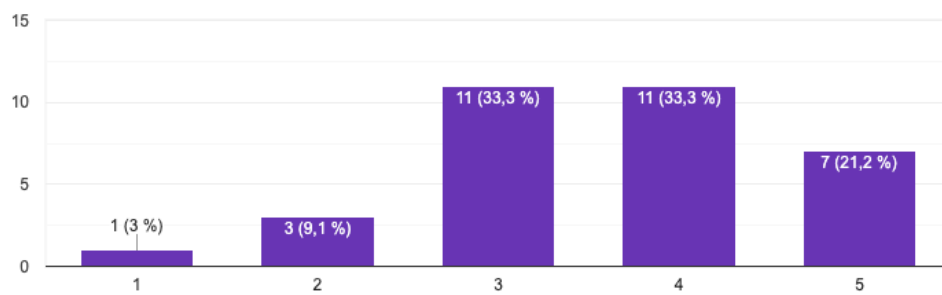
Figure A.4: Appealing & fun Video 2

User friendly & clear
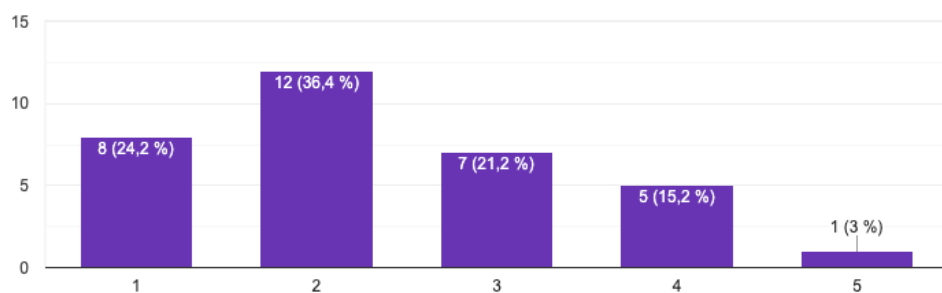
33 respuestas

Figure A.5: User friendly & clear Video 3

Appealing & fun

33 respuestas
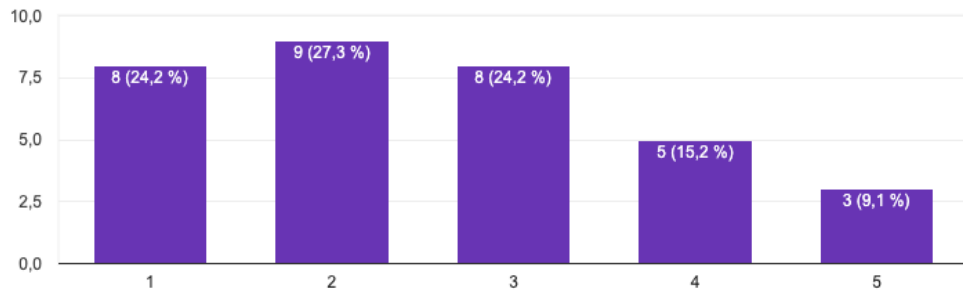
Figure A.6: Appealing & fun Video 3

User friendly & clear
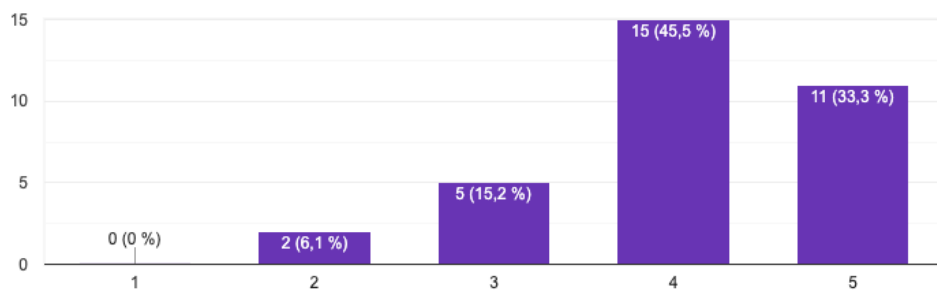
33 respuestas

Figure A.7: User friendly & clear Video 4

Appealing & fun

33 respuestas
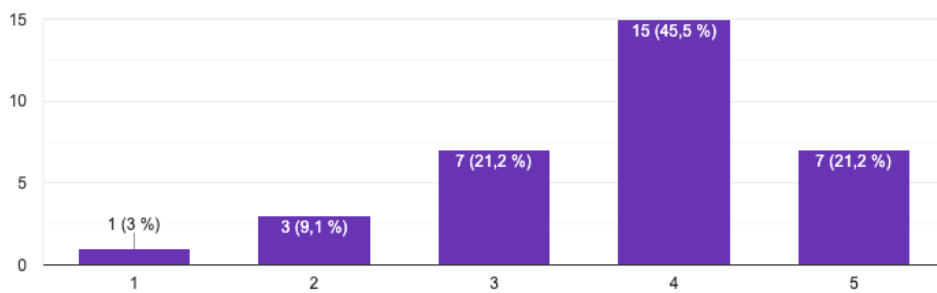
Figure A.8: Appealing & fun Video 4

User friendly & clear
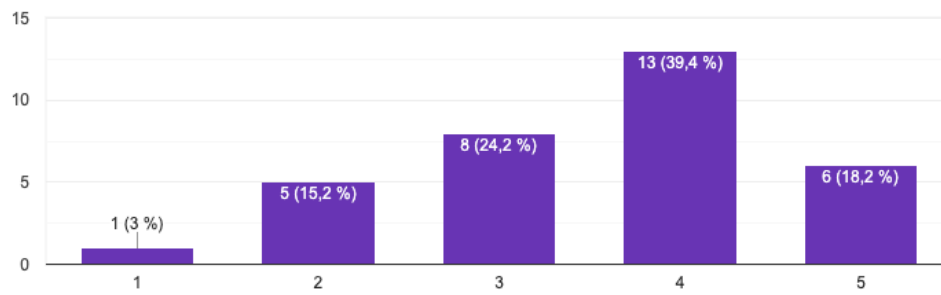
33 respuestas

Figure A.9: User friendly & clear Video 5

Appealing & fun

33 respuestas
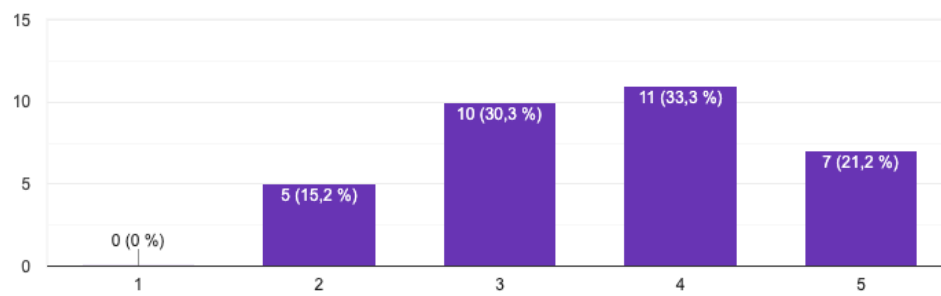
Figure A.10: Appealing & fun Video 5

Of the 5 videos, which style do you prefer most?

33 respuestas
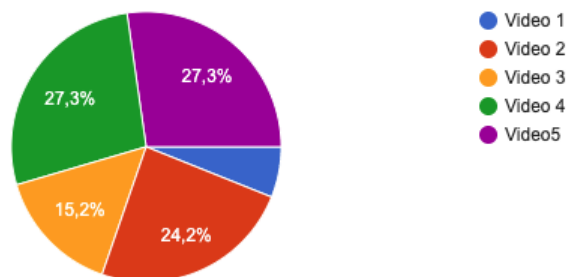
Which type of indication do you prefer

33 respuestas

- Words
- Arrows
- Moving/animated arrows

42,4%

9,1%

48,5%
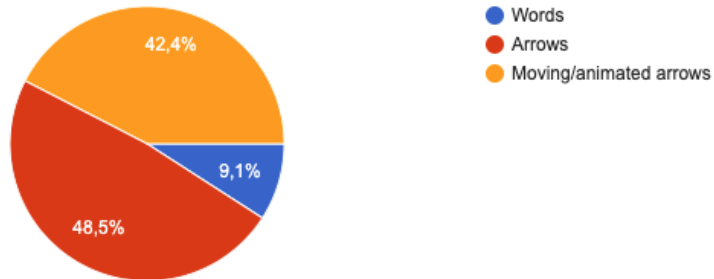
Would you prefer this type of application to be very neutral/professional or gamified?

33 respuestas

- Neutral (plain colours, clean, to-the-point, basic, only essential elements)
- Gamified (like a game, colourful, animations, rewarding sound/visuals)

39,4%

60,6%
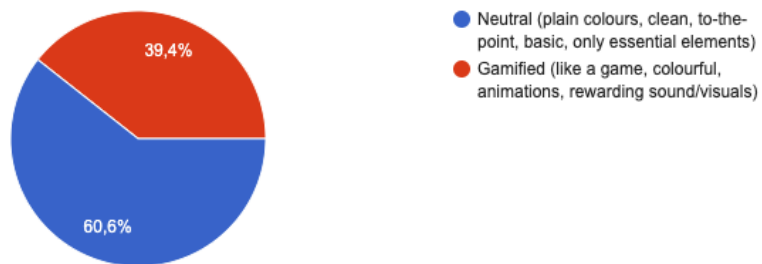
Would you prefer this tool to be an application or web-based tool?

33 respuestas

- Application: download & install
- Web-based: go to a website to use

15,2%

84,8%
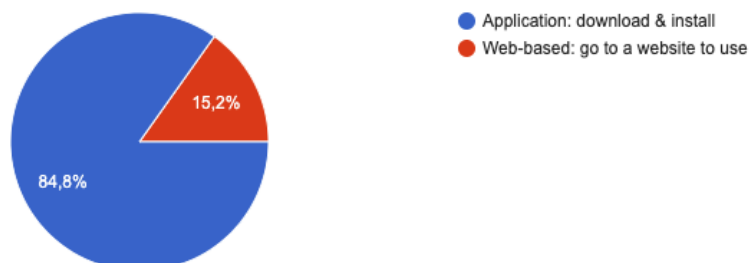
When you find a book with the app, which of the below would you appreciate?

33 respuestas
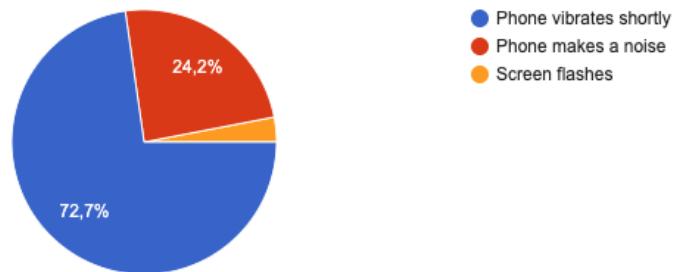
What is your age range?

33 respuestas
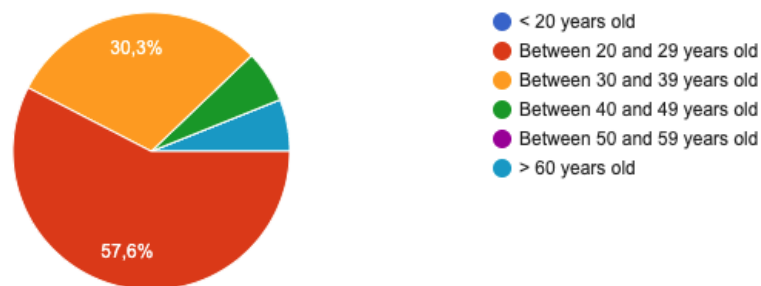
A.3   Answers Survey in Spanish

Basándose en la descripción, ¿cuan útil consideras que es esta aplicación?

33 respuestas
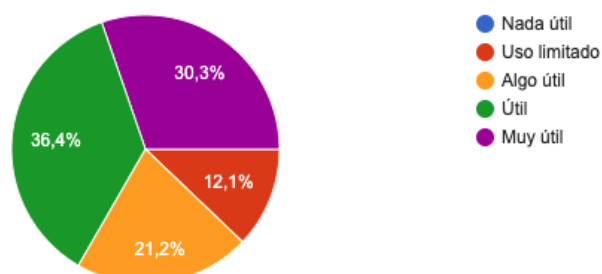
¿Actualmente sigues utilizando libros en tu casa o en tu entorno de trabajo?

33 respuestas

- ● Nunca
- ● Muy pocas veces
- ● Algunas veces
- ● Regularmente
- ● Todo el tiempo
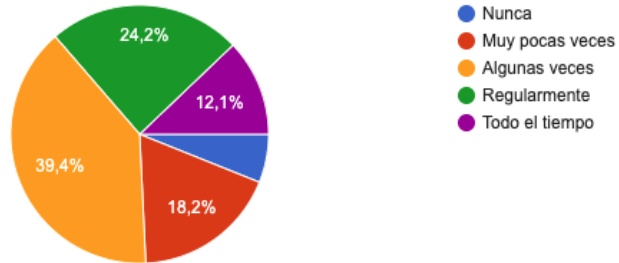
¿Estas familiarizado con el concepto de Realidad Aumentada (RA)?

33 respuestas

- ● Nunca escuché del tema
- ● El término se me hace familiar
- ● Conozco acerca del tema
- ● Lo uso en ocasiones
- ● Regularmente uso aplicaciones basadas en realidad aumentada

¿Tienes actualmente aplicaciones basadas en RA en tu teléfono u otros dispositivos? (Pokémon GO, IKEA, ...)

33 respuestas

- ● No lo se
- ● No, cero
- ● Si, una
- ● Si, dos
- ● Si, mas de dos
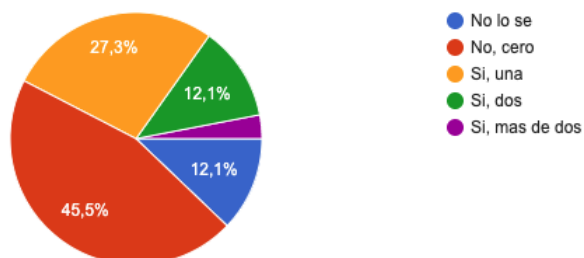
Claro y amigable con el usuario
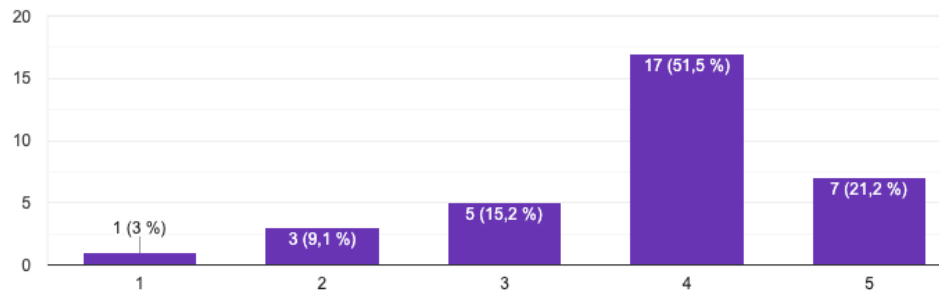
33 respuestas

Figure A.11: User friendly & clear Video 1

Atractivo y divertido
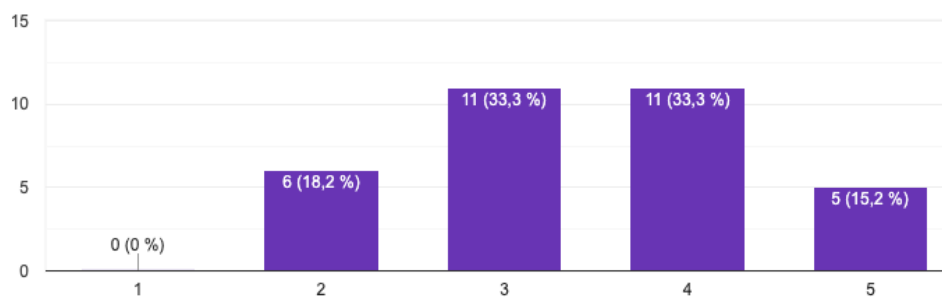
33 respuestas

Figure A.12: Appealing & fun Video 1

Claro y amigable con el usuario
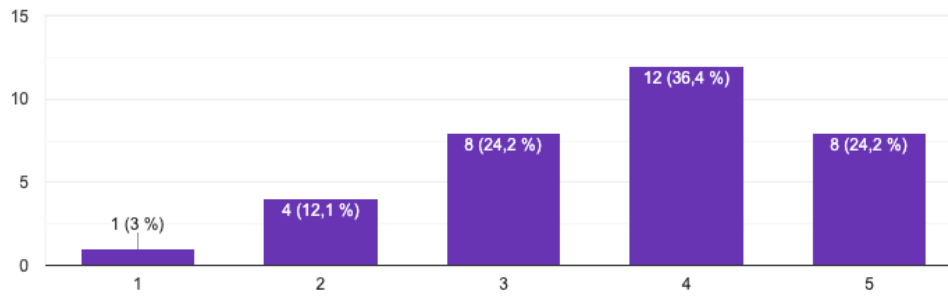
33 respuestas

Figure A.13: User friendly & clear Video 2

Atractivo y divertido

33 respuestas

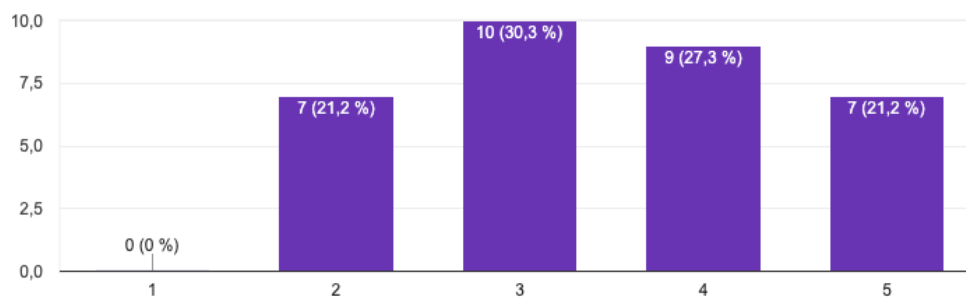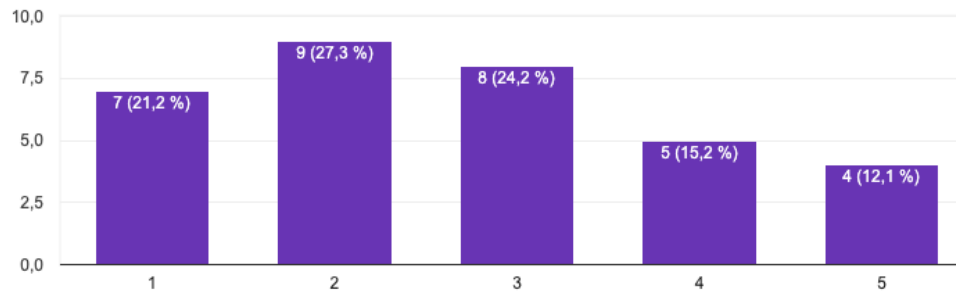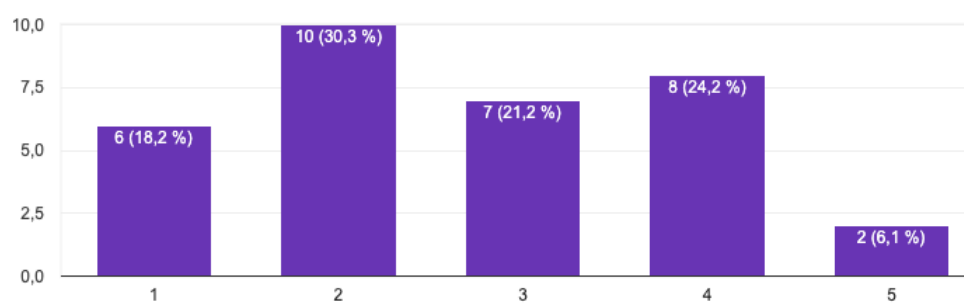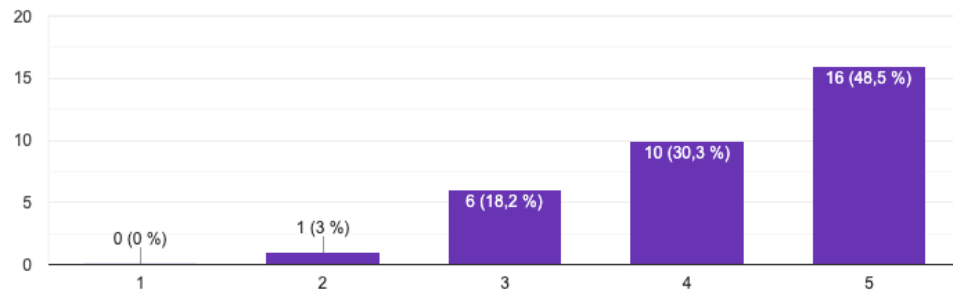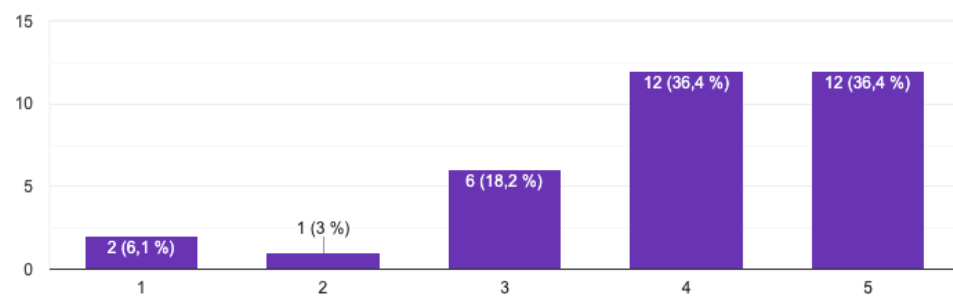Figure A.14: Appealing & fun Video 2

Claro y amigable con el usuario

33 respuestas

Figure A.15: User friendly & clear Video 3

Atractivo y divertido

33 respuestas

Figure A.16: Appealing & fun Video 3

Claro y amigable con el usuario

33 respuestas

Figure A.17: User friendly & clear Video 4

Atractivo y divertido

33 respuestas

Figure A.18: Appealing & fun Video 4
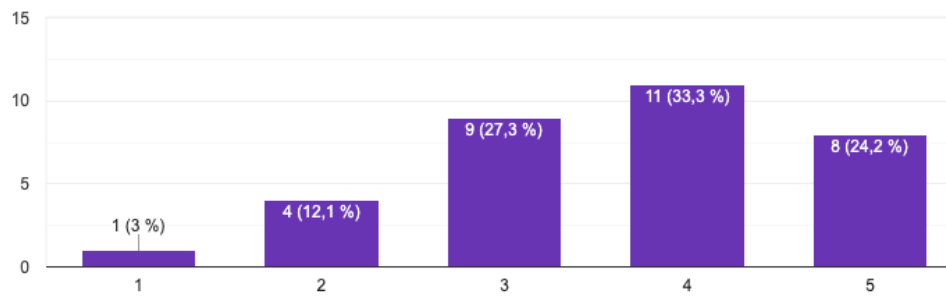
Claro y amigable con el usuario

33 respuestas

Figure A.19: User friendly & clear Video 5
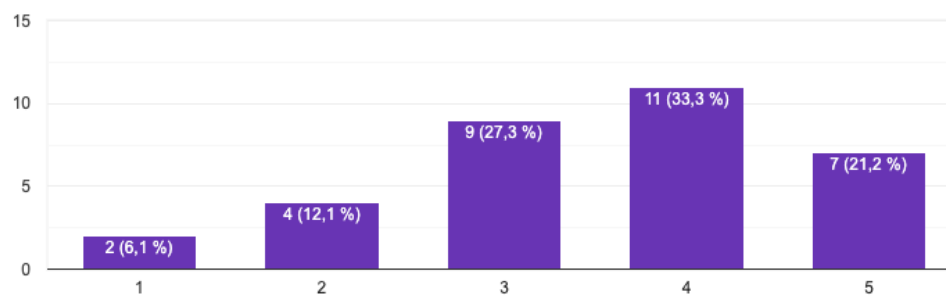
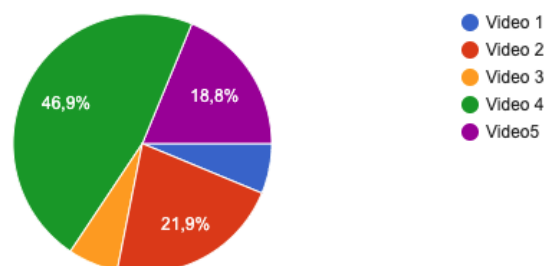Atractivo y divertido

33 respuestas

Figure A.20: Appealing & fun Video 5

De los cinco videos, ¿cuál es tu preferido?
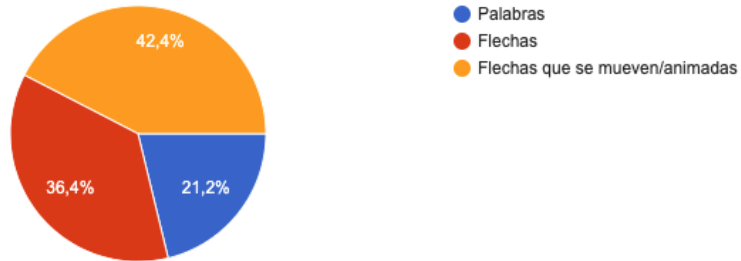
32 respuestas

¿Qué tipo de indicación prefieres?

33 respuestas

- Palabras
- Flechas
- Flechas que se mueven/animadas

42,4%
36,4%
21,2%

¿Prefieres que este tipo de aplicación sea muy neutral/profesional o mas parecida a un juego?

33 respuestas

- Neutral (colores lisos, limpios, sencillos, básicos, sólo los elementos esenciales)
- Como un juego (colorido, animaciones, sonidos/visuales gratificantes)

63,6%
36,4%
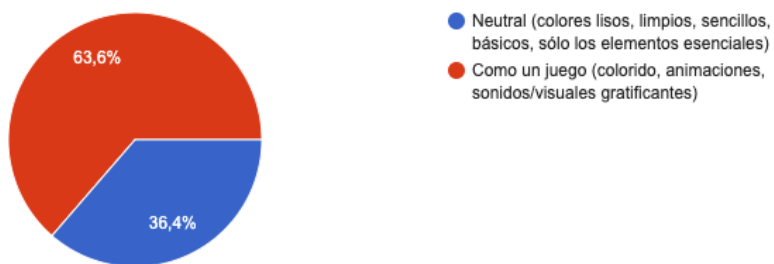
¿Prefiere que esta herramienta sea una aplicación o un sitio en internet en el que pueda registrarse?

33 respuestas

- Aplicación: descargar e instalar
- Basada en la web: ir a un sitio web para utilizarla

9,1%
90,9%
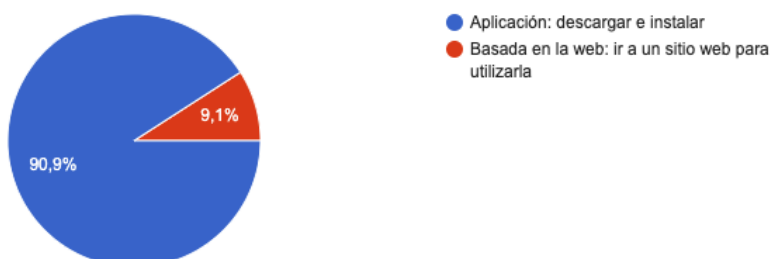
Cuando encuentres un libro con la aplicación, ¿con qué tipo de interacción te sientes mas cómodo?

33 respuestas

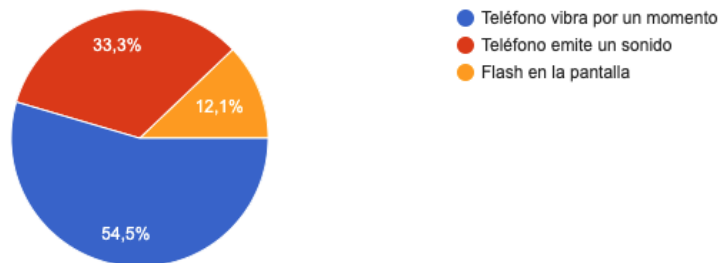- Teléfono vibra por un momento
- Teléfono emite un sonido
- Flash en la pantalla

33,3%

12,1%

54,5%

¿Cuál es tu rango de edad?

33 respuestas

- < 20 años
- Entre 20 y 29 años
- Entre 30 y 39 años
- Entre 40 y 49 años
- Entre 50 y 59 años
- > 60 años

9,1%

12,1%

75,8%
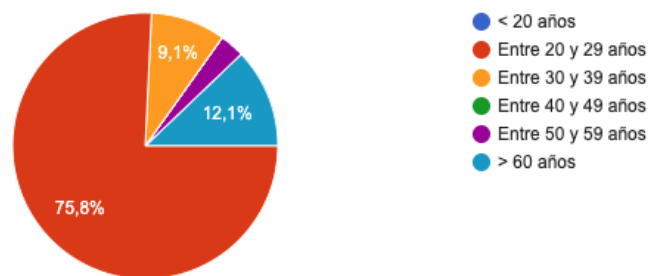
Disclaimer: The questions where the participants had the option to write feedback or provide additional information could not be included in this Master's thesis, but they can be provided upon request

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