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Master of Science in Applied Sciences and Engineering: Computer Science

AN AUGMENTED REALITY MUSEUM GUIDE

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Academic year 2019–2020

Promoter: Prof. Dr. Beat Signer
Advisor: Prof. Dr. Beat Signer
Faculty of Sciences and Bio-Engineering Sciences



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Afstudeer eindwerk ingediend in gedeeltelijke vervulling van de eisen voor het behalen van de graad Master of Science in Applied Sciences and Engineering: Computer Science

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“Deze masterproef is (ten dele) tot stand gekomen in de periode dat het hoger onderwijs onderhevig was aan een lockdown en beschermende maatregelen ter voorkoming van de verspreiding van het COVID-19 virus. Het proces van opmaak, de verzameling van gegevens, de onderzoeksmethode en/of andere wetenschappelijke werkzaamheden die ermee gepaard gaan, zijn niet altijd op gebruikelijke wijze kunnen verlopen. De lezer dient met deze context rekening te houden bij het lezen van deze masterproef, en eventueel ook indien sommige conclusies zouden worden overgenomen.”

“This master’s thesis came about (in part) during the period in which higher education was subjected to a lock-down 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”

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Abstract

In this thesis, we present the Augmented Reality Museum Guide. We explore the role of augmented reality (AR) in a museum context, and how it can bring a better museum visitors experience with more specific information about artworks and enable a more flexible access to information. We developed an application which improves the museum visiting experience using the advantages of augmented reality. The application introduces advanced information by the use of other knowledge sources rather than museum curators information. Augmented reality immersion will be supported by using a recent tablet, a portable device that would need to access a web-based application. The main usage of this Augmented Reality Museum Guide relates to let the user to walk and look at an artwork through the tablet. The other source of knowledge consists in the use of a Semantic Web database and where the data are linked together in a Linked Open Data (LOD) structure. In addition, to enable a more flexible access to other artwork information, the application prototype can also be used to visualise the artwork information in a 2D “Tree View” and to perform custom search. The main use of our application allows a visitor to look after artworks and to get information in an augmented reality interface. They can access this information by doing simple interactions, point and click. The result of this Thesis is relevant outcomes about our problem statements. The outcomes also are about the expectations of visitors regarding the artwork information. These results could be used as support for researchers that will extend our prototype and build an application with more functionality as described in our future work’s conclusion.

Contents

1	Introduction	
1.1	Problem Statement	2
1.2	Research Questions	4
1.3	Contributions	4
1.4	Methodology	5
1.5	Structure	6
2	Related Work	
2.1	Museums	9
2.2	Interaction Technology	11
2.2.1	Definitions of computer vision techniques	11
2.2.2	Review of existing applications	12
2.2.3	Comparison with our designed solution	16
2.3	User Experience	16
2.4	Semantic Web and Linked Data	19
2.4.1	What is the Semantic Web and Linked Data?	19
2.4.2	Use in museums	20
3	Information Survey and Requirements	
3.1	Information Survey	23
3.1.1	Question 1 Results	25
3.1.2	Question 2 Results	26
3.1.3	Question 3 Results	28
3.1.4	Survey Conclusion	29
3.2	Application Requirements	30
3.2.1	Non-functional Requirements	30
3.2.2	Functional Requirements	31
4	Augmented Reality Museum Guide	
4.1	General Introduction	33
4.2	Prototype Support	34
4.3	User Interface	35

4.3.1	Basic and Advanced information User Interface	36
4.3.2	Data Visualisation User Interface	37
4.3.3	Custom Search User Interface	38
4.4	Application Functionalities	40
5	Implementation	
5.1	Solution Overview	41
5.2	Server Side	43
5.2.1	Heroku & Flask	43
5.2.2	SPARQL Queries	45
5.2.3	Issues Encountered	46
5.3	Client Side	48
5.3.1	ArUco Marker	48
5.3.2	Augmented Reality User Interface	49
5.3.3	Artwork Data Visualisation User Interface	50
5.3.4	Custom Search User Interface	51
5.3.5	Request History User Interface	52
5.3.6	Issues Encountered	52
5.4	Testing	53
6	Use Case and Evaluation	
6.1	Use Case	55
6.1.1	Basic & Advanced Information Exploration	55
6.1.2	Data Visualisation Exploration	57
6.1.3	Customised Search	59
6.1.4	Requests History	60
6.2	Evaluation	60
6.2.1	Overall Reaction Results	63
6.2.2	Common User Interface Questions Results	64
6.2.3	Augmented Reality User Interface Evaluation Results	67
6.2.4	Artwork Data Visualisation User Interface Evaluation Results	67
6.2.5	Custom Search User Interface Evaluation Results	67
6.2.6	Requests History User Interface Evaluation Results	69
6.2.7	Artwork and Artist Information Evaluation Results	69
6.2.8	Evaluation Conclusion	71
7	Future Work and Conclusion	
7.1	Conclusion	73
7.2	Future Work	75

A Appendix

A.1	Artworks and Artists Informations Survey	80
A.1.1	Questionnaire	80
A.1.2	Result	82
A.2	User Experience And User Interface Evaluation	85
A.2.1	Questionnaire	85
A.2.2	Result	92
A.3	Step-By-Step Installation Guide	98

1

Introduction

From the invention of the Internet, the first public computers until now with the development of the Internet of Things, we are more and more connected to the Internet and spend more time on it and on our personal devices. This is partly due to the fact that access and content creation is much easier than before. As our interactions with data and the use of data have changed, this has led museums and research teams focus on how to integrate the use of connected devices into a museum visit. Museums were always a source of knowledge and learning. Moreover, the rapid increase in technology lead to a turning point in museum interaction. Studies about museums have therefore become a domain of interest in the discipline of human-machine interaction.

Having open access databases, such as DBpedia, and being increasingly connected to the Internet are sources of new interactions and sources of knowledge when visiting museums and exhibitions. The idea is to bring a pleasant and easy interaction, simple use to visitors, and an adequate use of the Semantic Web in combination with an augmented reality (AR) application within museums and exhibitions.

Augmented reality is a concept that allows virtual 3D or 2D objects to be embedded in a real environment. The principle is to combine the virtual and the real world and give the illusion of a perfect integration to the user.

Since the invention of smartphones and new technologies such as smart glasses including Google Glass or Microsoft HoloLens, it allowed to democratise the concept of augmented reality. Augmented reality is not yet fully explored, we will still have to wait to see its full potential used in the future. Video games, such as Pokemon Go, mixing reality and virtual reality have also helped to highlight this concept.

1.1 Problem Statement

In my thesis, we mainly identified two problems. The first problem is that museums currently offer only predefined and fixed information. It is difficult for visitors to easily get access to more detailed information about an artwork. The second problem is how to browse and display a graph with all the information related to an artwork.

Provide advanced information in supplement to basic information

This problem is related to the problem mentioned above, because if the integration of large graphs is achieved, then it is possible for visitors to have access to other advanced information about the work in addition to the basic information defined by museum curators. The basic information generally contains the name of the author, the year of creation of the artwork (if known), as well as a description of the artwork (not always available), as highlighted in **Figure 1.1**.

A smart way to access information data during a museum visit

Today as we know there are a lot of open source databases such as Wikipedia where we can find information. Then, it is easy to have a lot of information about an artwork, but it is complicated to know how best to integrate this with the content already present in museums. It is also difficult to know how to browse such a mass of data, and how best to arrange it in the shape of a graph. One way to do this is to use augmented reality to arrange the data about an artwork in an interesting way, while allowing the user to admire the piece of art at the same time. Below, we can see in **Figure 1.2** that the data attached to an artwork is vast compared to the basic information that a museum gives on the label that can be found next to the piece of art.

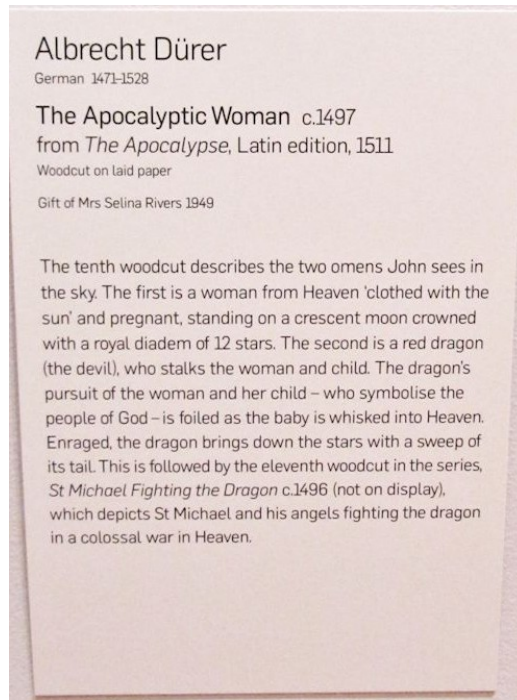


Figure 1.1: Example of labelled artwork

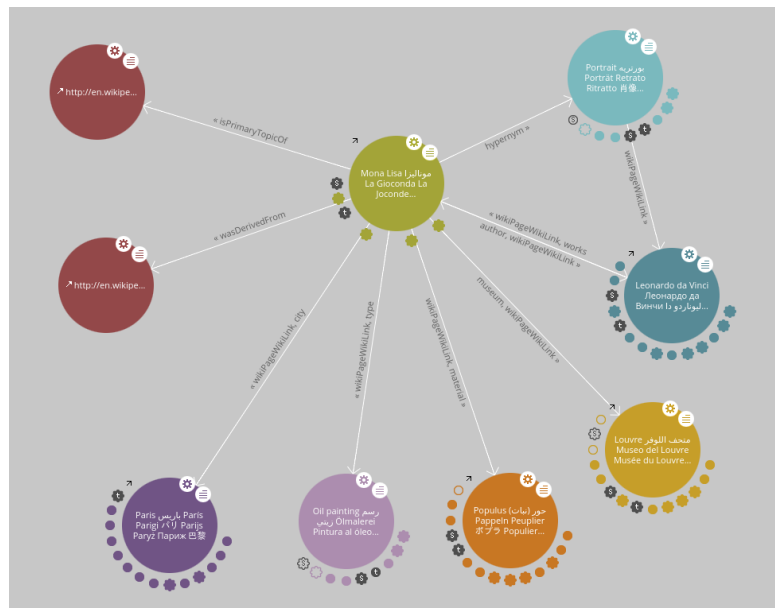


Figure 1.2: Example of an information graph related to the artwork Mona Lisa. Each colour point under a node represent further information linked to this node. Image capture made on <http://en.lodlive.it/>

1.2 Research Questions

In my thesis, we mainly have the following two research questions to which we will try to answer.

1. How to provide more flexible and advanced information to museum visitors?
2. How can we make the exploration of artwork information attractive and easy to interpret via augmented reality?

Artwork information exploration

In order to allow the exploration of the information dataset about an artwork, we will retrieve a basic graph by only looking first at a direct layer related to the artwork (i.e. the basic information). But when an end user wants to get advanced information, we will do other queries to get the other layers of the graph. It will lead to the creation of a large graph of all the artwork information. To do that, we will think to use an open source database.

Appealing user interface

To make the experience of a visit to the museum and the interaction with such a graph more attractive, we will use augmented reality technologies. We will create an AR interface that is simple to use and understandable for all types of end users. With these research questions, we will provide access through a mobile application to a broader source of information that can be explored, and to experience a new way of visiting a museum. We can also consider that visitors can use the application at home or other places to have access at artworks information, do custom searches, and past requests.

1.3 Contributions

The contribution of this thesis is the creation of a web-based application that will serve as a museum guide providing detailed information based on augmented reality. This application will allow a visitor to scan markers linked to an artwork and then have the basic information, as well as a graphical visualisation of the information linked to the artwork with the possibility of exploration. The contribution will also focus on how to visualise a graph of information in augmented reality, as well as on the exploration of the graph.

1.4 Methodology

We are going to use a “Design Science Research Methodology” (DSRM) [20], which is widely used in information systems research. The methodology consists of the following steps.

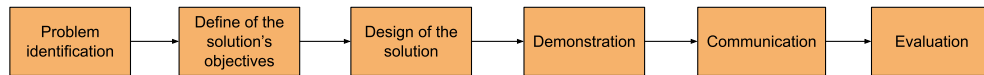


Figure 1.3: Steps of DSRM

Problem identification

We have already identified two major problems in this first introductory chapter.

Objectives

The definition of the objectives of our solution is made on the basis of the problems we have identified in **Chapter 1**, and on the work that has already been carried out, which we present in **Chapter 2**. With this and the content of **Chapter 3** which talks about our survey and the requirements of our application, we have therefore presented our final solution in **Chapter 4**.

Design of the solution

The design of our solution is derived from the problem we are trying to solve, as well as the objectives of our solution. It was also discussed at various meetings. Therefore, we have seen during these meetings the different design aspects of our solution. The descriptive aspect of our application is discussed in **Chapter 4** and the concrete, practical aspects of how it works are discussed in **Chapter 5**.

Demonstration and Communication

The demonstration and communication steps have been grouped together in one step for ease of use. Communication and demonstration were done during explanations to users for evaluation, during short briefings and during the defence of this thesis.

Evaluation

The evaluation of the solution was carried out remotely and internally with people, with discussions to determine their opinions on our application. Everything that was implemented and the results of this evaluation are available in **Chapter 6**.

1.5 Structure

Our thesis has the following structure:

Chapter 2 *Related Work*

This chapter covers the work that has been done previously. We discuss the main aspects that our solution will address. After discussing and presenting the works that has already been achieved, it allows us to refine our solution.

Chapter 3 *Information Survey and Requirements*

This chapter covers the survey, we carried out while presenting the results. These results help in the decision of the data that will be presented to the users, and also determine the requirements of our application taking into account the related work.

Chapter 4 *Augmented Reality Museum Guide*

In this chapter a solution is presented based on our requirements. Different prototype applications are also presented. Finally, we choose one of them, and list all the functionalities available in our application.

Chapter 5 *Implementation*

In this chapter, we describe how we implemented our application, and what choices were made in the technologies that build our solution. We also present a schema to summarise the behaviour of our application. Also, we discuss the issues encountered during the whole development and the solution that we found.

Chapter 6 *Use Case and Evaluation*

In this chapter, we present a basic use case of our application. Also, we present and discuss the process of our evaluation, as well as the presentation of the results of this evaluation. We discuss the general results of our application.

Chapter 7 *Future Work and Conclusion*

In this last chapter, we remember the difficulties encountered, as well as the positive aspects of our solution. We also present potential future and discuss what might be improved. In the conclusion, we discuss how our contributions, the approach used by our application try to solve our challenges and what we offer in our application.

2

Related Work

In this chapter, we analyse and discuss the related work to search for insights and conclusions about museum settings. It helps us to validate the problem statement or enhance it. We will first look at the underlying concept of a museum, before looking at what are the different computer vision techniques and what is computer vision, especially augmented reality, and how it has already been used. Also, we present what is the Semantic Web. All of this will allow us to validate and improve our solution against the problems described in **Chapter 1**.

2.1 Museums

HCI studies concerning museums have existed since the 1980s. With the expansion of the Internet, and technology being used in museums, this has made museums an important place for HCI studies. Museums are interesting places to study the behaviour and interactions of people from different backgrounds, social and intellectual levels. Because it allows researchers to have a broad range of the population.

What emerges from the HCI studies that have already been performed in museums is that digitalisation in museums and the interaction with it is influenced by different factors. These factors are the parameters, the technology used, the characteristics of the users as well as their expectations, the context of use and the social context. We also need to be aware of the problems a museum may have, as this plays a role in the success of the application.

As already mentioned above, the physical as well as the social context can influence the success of an application in the museum, but it can also influence the visitor's experience during their visit as reported by Falk and Dierking [7]. Other researchers also study their involvement in museums [22]. Thus, as described by Hornecker and Ciolfi [10] in their book, HCI is facing some trends and controversies. These controversies are about the memory of a site, the usage of the site [15], also about the fact that museums would not be neutral about the information given, and how best to use and display cultural heritage.

There are different kinds and types of museums: including art, history, military, automotive and technological museums. All these museums have the same primary purpose to share and show the history, the heritage of a nation, person or others [10]. Moreover, as already mentioned earlier, museums are not always neutral, because the data displayed is defined by museum curators who have their opinion and vision of the artwork. Also, this can be amplified by differences between museums regarding their sizes, budgets, organisations, and therefore these differences have to be taken into account in museum application design research [16].

Since different museums exist, there are tendencies to attract different types of visitors. Thus, it is important to know their motivations, what visitors are looking for when visiting a museum for real tests as well as the evaluation of its application [10, 11]. It should also be taken into account that sometimes user types can be mixed, such as parents with their children. There are also different types of experiences and satisfaction [6, 21]. The type of experience are: curiosity experience, facilitator experience, tourist experience, professionals. The different type of satisfactions are cognitive, introspective and social experiences. Concerning people's motivation, the motivations are quite diverse including curiosity, exchanges (discussion), to feel confident, to have some challenges, to feel in charge and control, and for playing. To know their motivations and expectations is an important thing, because not all people have the same expectations and motivations.

Customisation can also help to respond and provide a diverse experience for each person, because customisation can be experimented differently by people with the same application during a museum visit [10].

As stated above, the social context has a significant influence on the experience and the design of museum applications, as visitors observe each other and therefore may bias experiences if their interaction and their experience would be identical [9]. It should also be considered that some users do not follow a natural path in a museum and may therefore skip some elements that are critical to the digital tour.

Furthermore, an important reason for digitalisation and the use of new technology such as augmented reality in museums is the desire to attract new types of visitors who did not come before [10]. Finally, concerning the context of museums, it must also be taken into account that maintenance and also hardware/software can have two impacts in a museum. The two impacts are the ease of use (1) and a slight financial impact (2). This can lead to the failure of digitalisation in museums under any circumstances.

2.2 Interaction Technology

In terms of technologies that have been used in museums to bring user interaction and digitalisation, there have been tangible objects, mixed reality (MR), augmented reality (AR), and virtual reality (VR).

2.2.1 Definitions of computer vision techniques

In this section, we will look at the last three technologies mentioned just before. To define what augmented reality is, it is the process of placing 2D elements and 3D elements in the real world with the help of a computer. Thus, it is a superimposition of the real world with the virtual world to supplement the real world [32].

On the other hand, mixed reality is an extension of augmented reality, it is also a superimposition of two worlds, the real world and a virtual world. But it has the possibility of interacting with both virtual and real objects through the system used.

Thus, the notable difference between augmented reality and mixed reality is the interaction between the user and the real world. In MR, the user can interact with real objects at the same time as he or she interacts with virtual objects. Both objects and worlds coexist in the same environment. Finally, VR is only a computer-generated 3D virtual world, the user views the world around them by moving their head.

Therefore, there are several technologies, and frameworks to make augmented reality and several systems that allow the visualisation of this virtual world superimposed on the real world. Existing systems are smartphones, tablet, augmented reality headsets such as the HoloLens from Microsoft, Oculus headsets, for smartphones and tablets. This can be done through native application, or using a web browser. To create AR and VR applications, there are different frameworks such as ARcore, Vuforia, Wikitude, or the WebXR API. The three first mentioned frameworks are usable with all the systems mentioned before, as well as with web browsers. While the last framework WebXR is an API that is used through a web browser, and it can be used on any kind of device with a web browser including virtual reality headsets like the Oculus Quest.

2.2.2 Review of existing applications

The first application that was created for museums, and allows interaction with the visitor was the audio-guide. The first audio-guide appeared in the 1950s. The audio-guide is a mobile and individual device, which once a number is entered into the device or a detection is made near an artwork, it allows information on the artwork to be provided. The information is provided in slightly more detail than the basic information already provided by the artwork's label. But this information is not defined in a neutral way, as it is made by the museum curators. Therefore, it is difficult for a visitor who wants to find out as much information as possible and about what else they would like to know about the artwork. This kind of application isolates people from each other, as headphones are worn by visitors, which prevents real interaction between visitors when listening to the explanations.

The first applications for museums, which made use of computer vision technology, were developed in the 1990s. They used virtual reality to allow people to interact differently and to see the artefact from another angle. It also allowed people with disabilities to enjoy a visit to a museum using these applications [10, 26, 31]. Also, the use of virtual reality also allows people to make virtual museum visits without being there, as allowed by the project

“Goolge Arts and Culture”¹ managed by Google and in collaboration with various museums, this project exists since 2011. Thus, it allows people using an internet browser and from their homes to browse a museum in a virtual way, but also to see particular works with more information than is available during a simple museum visit. In addition, it is now becoming easy to use the VR with a smartphone and a viewer such as Google Cardboard, which is more affordable for museums, and also offers superior image quality compared to other available systems.

As reported by Gilliam [8], it is sometimes expensive to set up a virtual application in a museum, as Augmented Reality headsets are currently relatively expensive, and setup and configuration is difficult and requires dedicated staff. Maybe in the future, it will be more affordable as a technology, as it will surely evolve rapidly in the next few years.

There were many and modern applications that used augmented reality for museums. There have been a lot of studies concerning this from the 2000s until now. Therefore, we are going to look at some applications that have been carried out.

The first application realised was developed in 2004. It is an application for the archaeological site of Pompeii [35], and this study is part of a European LIFEPLUS project [28]. The aim of this study was to find a solution to improve user interaction. In order to do this, they used PDAs as a medium, and this choice is due to different factors: the first is that it is a small device, the second is that one can have a degree of freedom with the one superior to a more conventional medium, and the last is that one also has a better visual quality compared to the media available at that time in 2004. Concerning the user interface, they emphasised three principles: to give qualitative information as much as possible and that interests the user (1), that the style of the application is flexible for the users (2), and that the evolution of the application is easy for new platforms or new presentation (3). The application allows users to navigate and find their way around the archaeological site, to create their own tour with the possibility of walking around freely, and to choose predefined tours based on themes. Augmented reality was used to visualise the monuments as they were before the tragedy. They used a head-mounted system that was connected to the PDAs. The researchers called it “light AR”.

¹Google Art And Culture Project : <https://artsandculture.google.com/partner?hl=en>

Woods et al. [39] presented another museum guide application. They used the AR for an educational purpose. In this research paper, they used different techniques of AR: used tags to anchor the 3D Object and to track the objects. This research revealed some educational benefits, because it brings information in a more enjoyable way about temporal, contextual and spatial facts.

Two research studies in 2008 present museum application using AR to give information to the visitor. In study of Damala et al. [4], their prototype gives information about description of the work, technique (how it was made), description about the image, the context of realisation and artist information. Miyashita et al. [18] presented a museum application in relation to the Louvre museum. This application was designed to give information about artwork and also to help visitors to navigate in the museum. Both applications used basic AR devices and frameworks.

In the work of Wein [37] and the Smartify app², they used both image recognition to know the artwork. But in Wein's study, they also used QR code and numbers to help in the recognition of the artwork. They propose both "predefined content about the artwork", but more advanced than the basic content available in the museum. Only the application of Wein used AR to display the content to the visitor, and they also used basic AR techniques, devices.

In 2017, a study of Ding [5], who spoke about augmented reality in museums, presented two applications: "Artlens 2.0" from the Cleveland Museum of Art and "Skin and Bones" from the Smithsonian Museum.

The first application "Artlens 2.0"³ has the aims of improving the communication between visitors. Their app does image recognition, helps you to navigate in the museum, lets the possibility to choose a tour or lets you make your own tour by choosing artworks that you want to see, save favourite artworks, be notified of the museum events when one popup, used a dynamic and up-to-date catalogue because they maintained it in real-time, provided information like name, date, support, also tombstone information if it is a monument, videos if available.

²Smartify:<https://smartify.org/about-us>

³Cleveland Museum: <https://www.clevelandart.org/artlens-gallery/artlens-app>

The aim of “Skin and Bones” application⁴ is to have more engagement with students, school visits, and to give them a possibility to learn new thing in another way than the regular one. They propose to the visitor to have the possibility to see how the species move and look when the species are alive. Researchers want to make museums more accessible for everybody. For both applications, the researchers used AR with mobile devices, basic frameworks and techniques.

Nowadays, with the increase of technology, there is a new way of integrating AR in museums via the Projected Augmented Reality. It is mostly the same as done with devices to bring AR. It is a 3D object projected as a hologram, then there is no need of devices [10]. But with this technique, we lose the interactivity that a user would want. This technique could be used in combination with a head-mounted device or smartphones to get the interactivity.

About mixed reality, there have already been some studies that have made applications for museums. We will describe two applications HoloMuse and ARtLens [24, 25]. Each of these applications uses modern technologies such as Microsoft HoloLens augmented reality glasses. They are designed to help people to better visualise artefacts using mixed reality so that they can interact with them and also get additional information. Therefore, with these applications, users become active in their visit and become more involved. Moreover, by wearing a helmet, our field of vision is not blocked, it is still possible to view the artwork in question.

To conclude this part, there are some outcomes of the different applications and studies cited above. The intention of almost all the studies that have already been done, it is to find the right design principles to make augmented reality applications enjoyable. It also emerges that most of them have an educational purpose, to make museum visits more enjoyable, to increase the visiting time and attendance in museums. It must be taken into account that these applications must be able to help museums to achieve their objectives and also help with their changes. Therefore, in order to be successful, an application must take into account the needs of the users, the context, the specific requirements of each museum, to be simple and clear to use.

⁴Smithsonian Museum: <https://naturalhistory.si.edu/exhibits/bone-hall>

2.2.3 Comparison with our designed solution

Above, we described some studies and applications carried out using computer vision, particularly in augmented reality. We will use some of them for a comparison with the solution we propose. The applications used in this comparison will be Artlens 2.0, Smartify and HoloMuse. The purpose of this comparison is to highlight the points that our prototype can solve and that the other applications do not take into account. In contrast to our application, the reviewed applications all use only predefined data, do not offer a custom search possibility.

Therefore, the visitors have the possibility to be interested and to have more information related to the work of art. From a technical point of view, they all use basic frameworks. We plan to use the WebXR API. The reasons for this choice are simple, we do not want to be restricted to only one type of support. Since our application will be web-based and it can be both semi-immersive to immersive. Moreover, on the implementation in a museum, it will be simple with little extravagant cost to get hardware or other, unlike HoloMuse.

	Our Solution	Artlens 2.0	Smartify	HoloMuse
Advanced Information	Yes	No	No	No
Custom Search	Yes	No	No	No
Use of Semantic Web	Yes	No	No	No
Immersive visit experience	Yes	Yes	Yes	Yes
WebXR framework	Yes	No	No	No

Table 2.1: Comparison of Artlens 2.0, Smartify and HoloMuse with our own solution

2.3 User Experience

User interaction is an essential part of the user experience when visiting museums. On the whole, many things can influence a visit and therefore the user interaction, the influencing factors are the environment, the type of medium used, the inputs and outputs used, and the social context. In museums, HCI researchers have highlighted the fact that there are different types of interactions:

- Embedded and embodied interaction: it is a little interaction, inter-linked between artefacts and materials.

- Extend reality interaction: use the overlays of virtual world with the real world to bring interaction with content, and materials.
- Multi-sensory interaction: the interaction is brought by triggering our senses: audio, visual, tactile, olfactory.

Since we are going to use augmented reality, we are going to mainly focus on **“extend reality interaction”**.

Before we really address the interactions made using augmented reality, we quickly outline what is done in embedded and embodied interaction. One of the most used installations, bringing this kind of interaction, is through the use of standalone installation in museums, for example with the use of interactive tables. These installations are often placed away from the artworks, as this could lead to a general appreciation of the artworks. However, they are also sometimes placed close to the artworks to provide additional information support. It has been shown by researchers [10] that the interaction with the installation can be influenced. It can be influenced by the size of the room, the size of the screen, as this can prevent a group of visitors from gathering around the table at the same time to exchange on its content and enjoy it all together. One good thing about this kind of installation is that it can help people with disabilities. Furthermore, it also showed that when looking at the log files of this kind of installation, it appears that visitors spend less than a minute at installations and only look at the beginning of the information provided. The researchers notice also that during a visit, most people want to read the least possible [12]. To conclude on this type of installation, it is therefore important to consider where it is placed, what is going to be the content of such installations, and how it is going to be designed it in such manner to not lose the commitment of a visitor to be active during the visit.

About extend reality interaction, the first uses of augmented reality date back to the 1980s. Also, the user interaction is different when using digital media. The influencing factors are the same as already presented above. What makes the use of augmented reality popular and gives good user interaction are various things. Augmented reality in the user experience brings the possibility to see an artwork from a new perspective. Also, to have good user interactions, it is necessary to choose a suitable medium as reported in this study, which compares tangible and phone support [10, 14].

In this study [23], it is reported that interactions using a tangible medium are more appreciated by visitors. It engages the user more deeply in their

visit, makes the visitor active in their visit. Moreover, using a smartphone is pleasant, because it brings the ability to personally select what the visitor wants to know. The use of a mobile device is more feasible with a young audience.

There is also an era of ‘Bring your own device’ (BYOD), as this can allow the museum to just develop an application and make it available for download [10]. BYOD assets are multiple the costs in museums are reduced, not difficult to use and leaves the choice to the people to use the device or not. However, it is reported that this too has a possible negative impact on the visitor: a distraction from the artwork, an isolation from other visitors. Some people find that museums themselves have to make the mobile media available. Furthermore, it showed in the study conducted by Tillion et al. [30], that the use of a smartphone is more important than the time spent looking at an artwork. It is said that during a visit the use of a mobile device decreases until it is no longer used at all. Therefore, this shows that in the user experience, the use of a mobile device such as a smartphone must be as thoughtful as possible to avoid any use other rather than the initial use.

In addition, the interaction to access the data must also be user-friendly. In Wein’s study[37], they used the image recognition as well as other techniques such as markers and numbers. They showed from an evaluation with visitors that they prefer image recognition, but that the use of markers is a solution that helps in positioning augmented content, and can also help in case of image recognition issues. As reported by Atkinson[1], the use of markers is a popular technique, simple and requires little infrastructure.

Also, in most of the applications presented in the previous section, it is reported that the interaction brought by the use of AR is something enjoyable and engaging. Users appreciate being able to enjoy and learn new things [4, 24, 25]. They also appreciated the fact of being able to see the important details of an artwork, and found that the augmented content is simple to understand, and that there is also good interaction [18].

About the social aspect of the interaction, this intervenes in the pre-visit and post-visit. It also plays an important role in the user experience. In order for a visitor who wants to return to an application or a museum website after a visit, they need a lot of motivation. They can access it for example to be able to relive the visit, discover photos taken during the visit [10]. This is an important part of the user experience. Moreover, the strategies put in

place to make as many people as possible want to do a post-visit activity are numerous: the implementation of a loyalty program, a newsletter about upcoming events, exhibitions in the museum, the implementation of hybrid, digital or physical souvenirs, the possibility to save content on an artwork in order to access it later. However, this is very rarely done by visitors after the visit. On the other hand, it has been shown that it has a greater impact on those who plan to visit the same museum again. Also, one of the keys to good social interaction is the discussion of the artefact between users. This last point is therefore a more local social interaction that takes place in the museum directly, while the previous ones are a more an external social interaction.

To conclude this section, it is therefore important to remember that to have a good user experience, one must be aware of the environment in which the application will be used, have chosen the right type of media, and have made consistent design choices. In addition, this has allowed us to realise that the use of a smartphone can distract, isolate, but in our solution we will avoid this by offering a support that offers no other source of distraction than our application. Our application will not replace a visit, but comes to support visitors during their visit by providing more information in a flexible way.

2.4 Semantic Web and Linked Data

2.4.1 What is the Semantic Web and Linked Data?

The first occurrences of the word “semantic web” appeared in the late 1990s, early 2000. It was coined by one of the founders of the World Wide Web, Tim Berners Lee [3, 29]. Tim Berners-Lee’s vision of the semantic web is that it should be seen as an extension of the WWW, i.e. to make data available on the Internet interpretable and usable by machines. In order to achieve this, there is a need to add data (descriptions) to new data published, but also to existing data, so-called metadata. To create and organise this, there have been appearances of new standards and concepts such as RDF/RDFS⁵, XML⁶, OWL⁷, ontology [3, 38]. RDF (Resource Description Framework), XML (Extensible Markup Language) and OWL (Web Ontology Language) are all languages used to represent data as a structure or model.

⁵RDF documentation:<https://www.w3.org/RDF/>

⁶XML documentation:<https://www.w3.org/XML/>

⁷OWL documentation:<https://www.w3.org/OWL/>

An ontology is a structure, a model composed of terms, concepts that all together represent information, as well as relationships between this information. Applications related to the semantic web are various and widespread in our daily life, one of its uses in our daily life is for example the use of a voice assistant such as Siri from Apple or Alexa from Amazon.

Linked Data appeared a few years later in 2006 when Tim Berners-Lee first mentioned it [2]. Linked Data is described by him as the heart of the semantic web. It is seen as a data structure, linked with other data, it is useful for semantic queries.

Linked Data can again be seen as a way to make data available online. This concept is at the basis of some technologies such as RDF, URI as already mentioned above. Tim Berners-Lee explained that there are four basic principles: a unique identifier, the use of a unique HTTP address to access other data, the use of standards to make the information relevant and the use of a link with a unique identifier to other resources. For applications, this is used in open access databases, as well as in ontologies, such as DBpedia, Wikidata, FOAF or UMBEL.

2.4.2 Use in museums

As already described in **Subsection 2.2.3**, it was easy to notice that none of them used external sources of information other than the one defined by their experts for the information offered to visitors. Moreover, there have been very few studies carried out that demonstrate the use of the semantic web, especially linked data, within museums [27, 33, 34]. In the existing research on the subject, several interesting things emerge that are common to all of them. We can get this linked data from two sources: semantic databases or from a museum database. We plan to use in our solution, the resources that come from DBpedia (semantic database) because this one is better standardised than museums that have their own way of structuring their data. The resources of DBpedia are more neutral than museum information because the information are made by their experts. To execute these requests, on the DBpedia endpoint, we can do it in two different manners as it is described in one of the studies cited above. We can do it either directly from the support which is used to access the application, or another solution simpler is to do it from a server that communicates with the visitor's support.

Therefore, to ensure a certain quality of the data provided to the user, it is also important to process and sort the data in order to display relevant

data to the user. Finally, as said above that there is a disparity between semantic databases and museum-specific databases, it might be good to have the possibility for databases to try to make their data uniform in terms of structure.

Moreover, in 2010, a Finnish museum [13] had the idea to realise a framework allowing them to convert databases into data seems like the one contained in DBpedia in order to be able to integrate them there afterwards. To conclude, the use of the semantic web is useful and with the help of augmented reality, it takes the museum in an interesting and promising direction.

3

Information Survey and Requirements

In this chapter, we present the results of the survey we conducted. We also discuss and present the requirements of our application.

3.1 Information Survey

As described in the related work, when using DBpedia, one can have a lot of data when querying for an artwork. Therefore, we think that is essential to conduct a survey to get the correct and meaningful information about artworks. We conducted a survey around people to gather what basic and advanced information is considered useful concerning artists and their artworks.

The results of this survey will allow us to elaborate the basis of our requests that will be used in our solution. Our survey is composed of three questions in total and each question has predefined answers. The participants have the possibility to enter their own answers as well.

- Question 1: “*What basic information about an artwork would you like to have in addition to title, artist, year and artwork’s description?*”
 - Art movement
 - Materials used as support
 - Some information about the artist (nationality, birth date and date of death, style)
 - Type of painting (e.g. oil painting, ...)
 - Whether there are other artworks made by the same artist in the museum
 - Other

- Question 2: “*What advanced information about an artwork would you like to have in addition to the basic one?*”
 - List of artworks from the same century
 - List of artworks of the same style
 - List of artworks made by the same author
 - More pictures of the artwork
 - List of interpretations and replicas of the artwork
 - Useful links concerning the artwork (scientific articles, press articles, ...)
 - Size of the artwork
 - Other

- Question 3: “*What basic information about an artist would you like to have in addition to their name, nationality, birth date and date of death, gender and list of artworks made?*”
 - Art patron (sponsor)
 - Disciples (students)
 - Art movement, painting style
 - Birth name
 - Pictures
 - Influencer of and influenced by (list of people)
 - Useful links
 - Other

A total of 41 people completed our survey, and answered all three questions. People were allowed to choose several answers for each question.

3.1.1 Question 1 Results

We asked this first question: “*What basic information about an artwork would you like to have in addition to title, artist, year and artwork’s description?*”, because in museums most of the time concerning the information given to the user is just a title, a year, the author and the description. Therefore, we wanted to know if the visitors would like other basic information. A graph of the results in question 1 is shown in **Figure 3.1**.

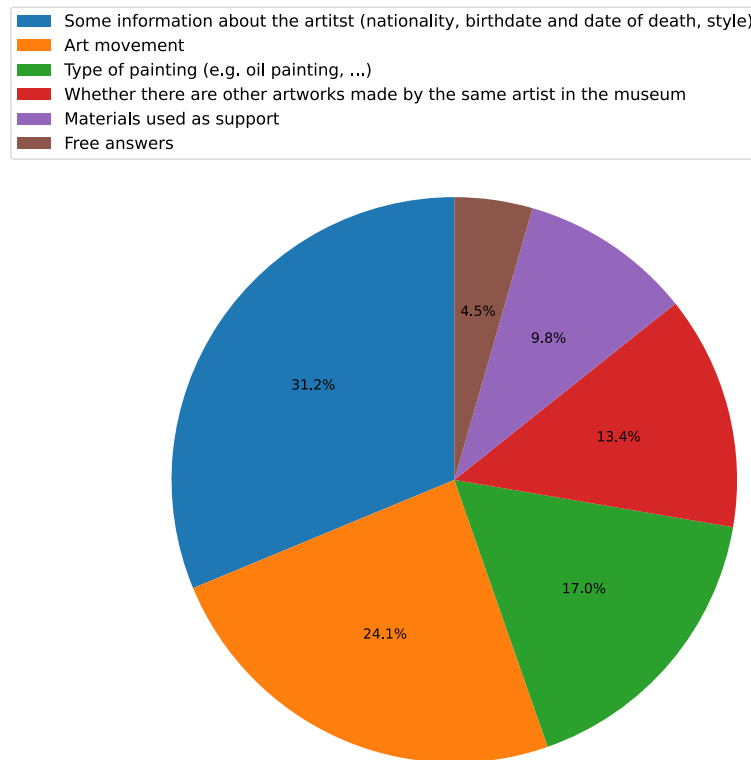


Figure 3.1: Pie chart of results for question 1

We can see that among all the answers to this question, there is one answer that stands out the most among all, the answer is ‘*Some information about the artist (nationality, birth date, and date of death, style)*’. We can see that

the other answers that also stand out are: ‘*Art movement*’, ‘*Type of painting (e.g. oil painting, ...)*’, ‘*Some information about the artist (nationality, birth date, and date of death, style)*’, ‘*Whether there are other artworks made by the same artist in the museum*’, and ‘*Materials used as support*’. The rest of the answers at most one percent are open answers from the participants. The open answers are few but high quality. On the other hand, there is a free answer which is covered by question 2, the answer is about the dimensions of the work. For this question 1, we will use all the predefined answers as basis information for our solution.

	Number of Answers
Some information about the artist(nationality, birth date and date of death, style)	35
Art movement	27
Type of painting(e.g. oil painting, etc.)	19
Whether there are other artworks made by the same artist in the museum	15
Materials used as support	11
Explanation about how to possibly interpret the artwork (Free answer)	1
History of the painting (Free answer)	1
Dimensions (Free answer)	1
Meaning of the artwork (Free answer)	1
‘Augmented Reality’ ->3d views, short clips from documentaries on the making of, the life of, the art period, a 3d time line and links with other work, corresponding music from that time, ... so much more than static info I could also read from a small note next to it (Free answer)	1

Table 3.1: Number of answers by choices for question 1

3.1.2 Question 2 Results

About the second question, we asked: “*What advanced information about an artwork would you like to have in addition to the basic one?*”, to know if the visitors would like more detailed information about the artwork. A graph of the results in question 2 is shown in **Figure 3.2**.

We can see that among all the answers to this question, that there is one answer that stands out the most among all, the answer is ‘*List of artworks made by the same author*’. We can see that the other answers that also stand out with more than ten percent are: ‘*List of artworks of the same style*’, ‘*List of artworks of the same style*’, ‘*Useful links concerning the artwork (scientific articles, press articles, ...)*’, and ‘*List of interpretations and replicas of the artwork*’. The rest of the answers are under the ten percent for the predetermined answers and under one percent for each open answer from the participants. The rest of predefined options are also good, but less appreciated than the first four predetermined answers as shown in **Table 3.2**. By knowing that, we will use only the first four results in our application to build our request system.

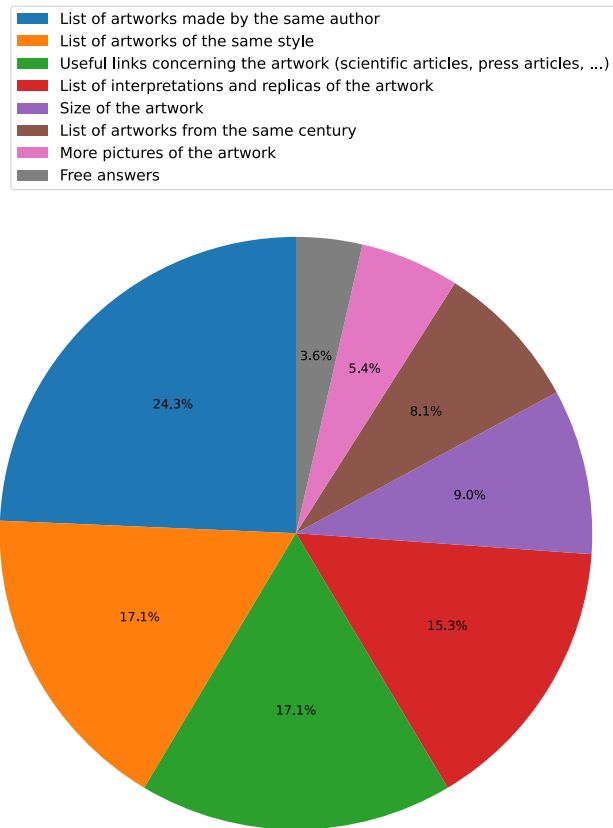


Figure 3.2: Pie chart of results for question 2

	Number of Answers
List of artworks made by the same author	27
List of artworks of the same style	19
Useful links concerning the artwork (scientific articles, press articles, ...)	19
List of interpretations and replicas of the artwork	17
Size of the artwork	10
List of artworks from the same century	9
More pictures of the artwork	6
Remarkable facts about composition, details (Free answer)	1
Information about the context it was painted in : politic, economic, to have an idea of how it influenced the art. (Free answer)	1
Some information about where the artwork was supposed to be exposed (and for really important artworks a reconstitution in virtual reality of this place) (Free answer)	1
Same remark as the first point. Show how the restoration worked in a small clip, highlight the interesting parts in an overlay, (Free answer)	1

Table 3.2: Number of answers by choices for question 2

3.1.3 Question 3 Results

For the last question, we asked: “*What basic information about an artist would you like to have in addition to their name, nationality, birth date and date of death, gender and list of artworks made?*”, because in museums all the time there is only one artist’s information given to the visitor, it is the name of the artist. Therefore, we wanted to know if the visitors would like other basic information about the artist. A graph of the results in question 3 is shown in **Figure 3.3**.

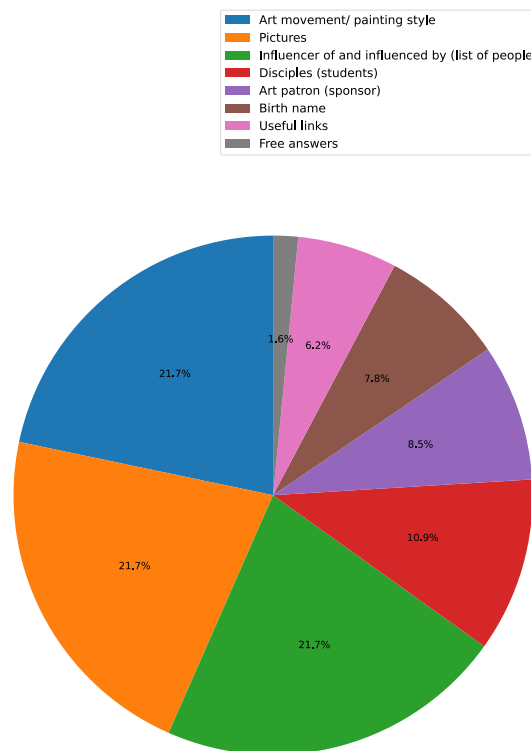


Figure 3.3: Pie chart of results for question 3

You can see that among all the answers to this question, that there are three answers that stands out the most among all. The three answers are

‘Art movement/ painting style’, ‘Pictures’, and ‘Influencer of and influenced by (list of people)’. After with almost eleven percent, the fourth answer is ‘Disciples(students)’.

The other predefined questions have good results, eight percent, seven percent, and six percent as can be seen in **Table 3.3**, but are less desired by people. There were only two free responses from the interviewees. Those are interesting but will not be retained in the whole. But the last open answer shown in **Table 3.3**, the comment is really relevant and match with what we think about the data and their presentation. With all of that, we will use only the three first predetermined answers in our application to build our request system.

	Number of Answers
Art movement/ painting style	28
Pictures	28
Influencer of and influenced by (list of people)	28
Art patron (sponsor)	14
Birth name	11
Useful links	8
If he was recognised by it’s peers at the time of the painting, and if/if not : why (Free answer)	1
So all the info you propose could be there but the way you present it is more important than the what. Let the user select what he/she wants to see. (Free answer)	1

Table 3.3: Number of answers by choices for question 3

3.1.4 Survey Conclusion

In conclusion, with the results presented above, we were able to determine what would be used as a basis for our query system for the semantic database. To summarise by questions, here is what was chosen:

- Question 1: “What basic information about an artwork would you like to have in addition to title, artist, year and artwork’s description?”
 - Some information about the artist (nationality, birth date and date of death, style)
 - Whether there are other artworks made by the same artist in the museum
 - Art movement
 - Materials used as support
 - Type of artworks

- Question 2: *“What advanced information about an artwork would you like to have in addition to the basic one?”*
 - List of artworks made by the same author
 - List of artworks of the same style
 - Useful links concerning the artwork (scientific articles, press articles, ...)
 - List of interpretations and replicas of the artwork
- Question 3: *“What basic information about an artist would you like to have in addition to their name, nationality, birth date and date of death, gender and list of artworks made?”*
 - Art movement, painting style
 - Pictures
 - Influencer of and influenced by (list of people)

Furthermore, among the free answers from the participants, these answers are interesting, but for some of them are difficult to make with a simple query to only an open access semantic database. Thus, these will be considered for future work with other supporting technology, for more information see **Chapter 7**.

3.2 Application Requirements

The Augmented Reality Museum Guide aims to give the visitor the possibility to have more information about a work, its artist than the information given by the museum, and all this with the help of augmented reality in order to make it more enjoyable. Thus, we will describe the non-functional and functional requirements of our web-based applications.

3.2.1 Non-functional Requirements

As mentioned, we will create an augmented reality web-based application in the context of this Master Thesis. This application will run on tablet devices in order to have a screen wide enough to see all the information easily. For our web-based application, we will use an API called WebXR¹ to create the augmented reality content, fiducial markers for the positioning. We will also

¹WebXR documentation: <https://www.w3.org/TR/webxr/>

use the HTML and CSS languages to create the website and Python for the server part with the Flask framework, which is a micro web framework². In the future, our application will be easily supported by an augmented reality headset, as one of WebXR's features is to be easily portable on any support. To develop the application, we will use a basic IDE like Pycharm from JetBrains IDE tools³, text editor, and developer browser version because WebXR is for the moment only available as a draft version.

3.2.2 Functional Requirements

The first functional requirement of our solution is about the advanced information. Knowing that the information describes the artworks in museums, it is often poorly developed. Therefore, it is one of the most important features of our application.

In the previous subsection, we discussed and analysed the results of a survey that was conducted to determine the expectations about the information that visitors would like to have. To meet their expectations, we are going to use an open access semantic database called DBpedia, which will help us with queries to retrieve more detailed information about artworks and artists.

The second requirement, it is a requirement linked to the first one and it is about the queries. The queries will be done when an artwork is recognised and return all the information needed. This will also be used when a visitor wants to do a custom search about specific information. All the queries will be done using the SPARQL⁴ language and using the DBpedia endpoints. The information received will be displayed around the artworks using AR.

The third requirement will be the user experience. The user experience will be immersive by the use of a tablet with the AR content. The interface of the application will be easy as possible, all the content and functionalities will be displayed in a clear way to allow the visitors to understand them rapidly and enjoy the content. The interaction will be also easy, the visitor will have to scan the artwork fiducial markers and used the different button to access the advanced content or even to do a custom search on a specific subject.

²Flask documentation:<https://flask.palletsprojects.com/en/1.1.x/>

³Pycharm: <https://www.jetbrains.com/pycharm/>

⁴SPARQL documentation:<https://www.w3.org/TR/rdf-sparql-query/>

Furthermore, there are some more requirements:

- Information network: it will allow the user to interact with a whole network about the information related to the artwork.
- Customised search: it will allow the user to search specific information about artworks, techniques, artists or others.
- Requests history; to retrieve and displayed easily previous artwork search or customised search about a specific subject.

4

Augmented Reality Museum Guide

The aim of this chapter is to present our solution. To do this, we discuss the application in general, then describe the different theoretical aspects that make up our solution as well as the design of the application. Finally, we present scenarios and the final application prototype.

4.1 General Introduction

Our Augmented Reality Museum Guide application allows a visitor using augmented reality to access basic information as well as advanced information as discussed in the **Chapter 3**. The application allows to visualise and navigate all the data related to the artwork in a graph and finally to have the possibility to perform a personalised search. The architecture of our application consists mainly of two components. The first component is the client user interface, which can be accessed via a web browser. The second component is the server of our application which allows our application to be networked and to retrieve the available data from DBpedia and to process the data.

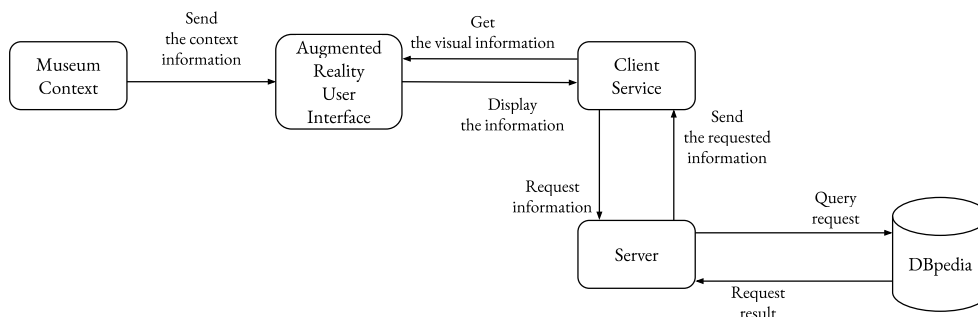


Figure 4.1: General architecture

Our user interface consists of information available using virtual objects in 2D and 3D, which will be integrated into the real world by superposition. We will retrieve identification information via visual markers displayed in the museum near artworks. **Figure 4.1** shows the workflow of our application. When a visitor uses the application to scan an artwork identifier marker, the client back-end service will send a request to the server to retrieve useful data about the artwork related to the marker. Once this request is received by the server, the server makes the different useful semantic queries to the DBpedia semantic open database and the results are sent back to the client in order to display the results.

4.2 Prototype Support

At the start of our reflections on how to approach the problems that we intend to solve, we evoked several types of prototype application and support. We focused on the different characteristics that our application should solve. Thereby, we had considered three different types of support.

The very first type of support that we considered was augmented reality goggles, like the Moverio BT-350¹. We had thought of this support in order to free-up the user’s hands, while still allowing them to see the artwork and not be distracted by using another device. However, after discussion and research on this medium, although it is interesting and runs on the Android system, we ruled it out because with approximately 23 degrees the field of view was too small.

¹Moverio BT-350: <https://www.epson.eu/products/see-through-mobile-viewer/moverio-bt-350#details>

The second support we had considered was a smartphone. The use of a smartphone was practical, requiring less hardware, and having a low financial impact for museums because of the concept of “Bring your own device”. However, we decided not to use it because we plan to have a graph of all information related to an artwork. Therefore, we are looking for a device with a sufficient screen size.

The last type of support we had considered was a tablet. The use of a tablet is practical, because it allows us to have a sufficient screen size, and to have the latest technology. It is a good support compared to other types of support. Therefore, we have chosen for our prototype to use a tablet running the Android operating system.

Moreover, we had considered two types of application that could be used in our chosen medium. The first type of application we considered was a native Android application. We chose this because making an Android application is simple. There are many frameworks providing access to the use of augmented reality in Android applications.

The second type of application we had considered was a web-based application accessible via a web browser. We had chosen this type of application because, unlike an Android application, we are not constrained to have our application usable by only one type of device. With this type of application, we make possible to use our web-based application on any type of device with a browser and an access to the Internet. Therefore, we have chosen this second type of application.

4.3 User Interface

In the previous **Section 4.2**, it was discussed that we are considering different platforms for our application. However, we knew that whatever the type of support, it would not influence the overall look of our user interfaces which would have been the same. We had a clear idea from the beginning about what our user interfaces should look like.

Our prototype will have different user interfaces. There is mainly three interfaces: the interface that allows the visualisation of basic and advanced information in augmented reality, the interface that allows the exploration of all the data related to an artwork in a graph and the interface that lets the visitor to perform personalised queries.

4.3.1 Basic and Advanced information User Interface

In order not to interfere on the view of the artwork and to have an easy-to-use interface, the interface is intended to be composed of only a few elements. In the centre of the interface, there will be the view of the artwork. At the bottom of the interface, the visitor will be able to see the name of the artwork as well as the artist and the year of creation. On the left-hand side, the visitor will be able to find the different buttons in the form of icons to access basic and advanced information, to scan a new artwork and to make a personalised search. As shown in **Figure 4.2**, this interface is the main interface of our application once a visitor has logged in and scanned a marker identifying an artwork. On the other hand, when the visitor wants to scan or to make a personalised search, the other buttons will not be accessible until the action is completed.

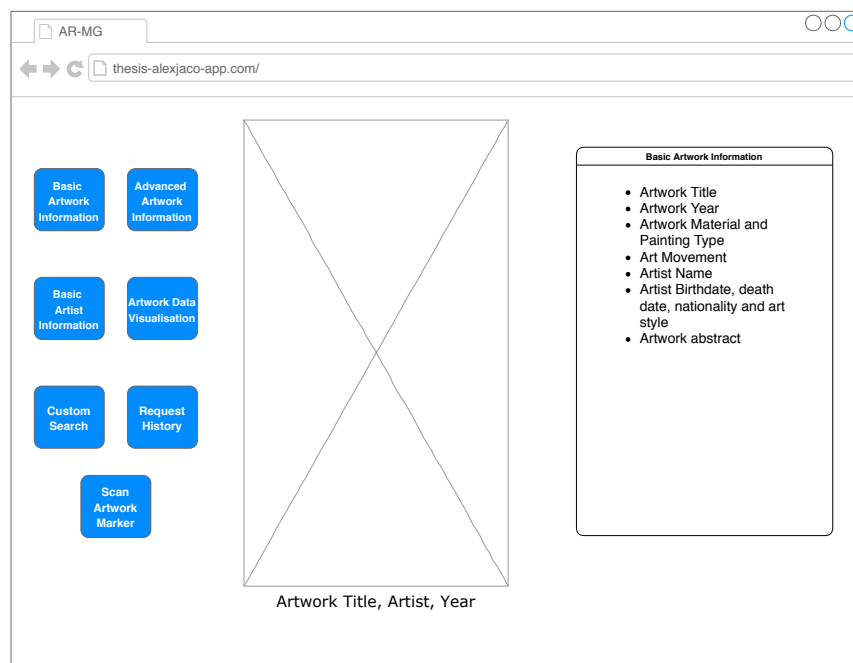


Figure 4.2: Mockup of Basic and Advanced Information User Interface

For the presentation of the data, we had the choice between two possibilities:

- A “quadrant” display, i.e. to have several rectangles surrounding the artwork containing information. This could be relevant in order to display all the information we could find about the artwork. However, this could be seen as a disadvantage because it would overload the visitor with information, and interfere with the visitor’s ability to focus on the artwork with all information on the surrounding area.
- A “half-quadrant” display, just like the quadrant display, will have areas where to arrange the information. We will only have an information area on one side of the artwork, the opposite side of the buttons, as illustrated in **Figure 4.2**. Therefore, we have chosen to display the data on half a quadrant, as this will allow the visitor not to be too distracted by the amount of information available. It will give them the opportunity to admire the artwork in the best possible conditions.

4.3.2 Data Visualisation User Interface

In addition to simply viewing an information area near the artwork, we also wanted to offer the visitor the ability to see all the data related to the artwork in a single graph and to browse that graph. We considered two graph designs after researching and reading books dealing with the visualisation of information, particularly the representation of large amounts of data in the shape of graphs and networks [17, 19, 36]. What emerges from this research is that we can present our data related to an artwork in the form of two different designs: the first design is a graph representing a network, and the second design representing the information in the form of a “Tree View” like the visualisation of file explorer.

In the first design, the basic idiom is to show the relations between the data, i.e. what is directly related to the work and what is indirectly related to it. In order to better visualise the links between the data linked to an artwork, we could use colours on each node to distinguish the different levels. On the other hand, with a large amount of data, this can quickly become unreadable for the user and difficult to navigate in the graph. To solve this problem, one can try to group the same nodes under the same node cluster. When the cluster is accessed, the regrouped nodes are visible.

About the second design, the idiom is to show the links in the content hierarchy as opposed to a network graph which is more to show the relationships between data. The data will be displayed as a “Tree View”, as shown

in **Figure 4.3**, like the hierarchical structure of a file system that shows files and folders. This design will be more readable to the visitor than a network graph. Because initially in this visualisation, all data will be closed at the root which is the title of the artwork. On the other hand, there is a small drawback when navigating. In order to access specific data, it is sometimes necessary to navigate far down in the tree. To solve this, once you get too far into the structure, we again do a query and display the results or redirect the visitor to a web page depending on the last information selected. In conclusion, we decided to use the “Tree View” visualisation for data representation.

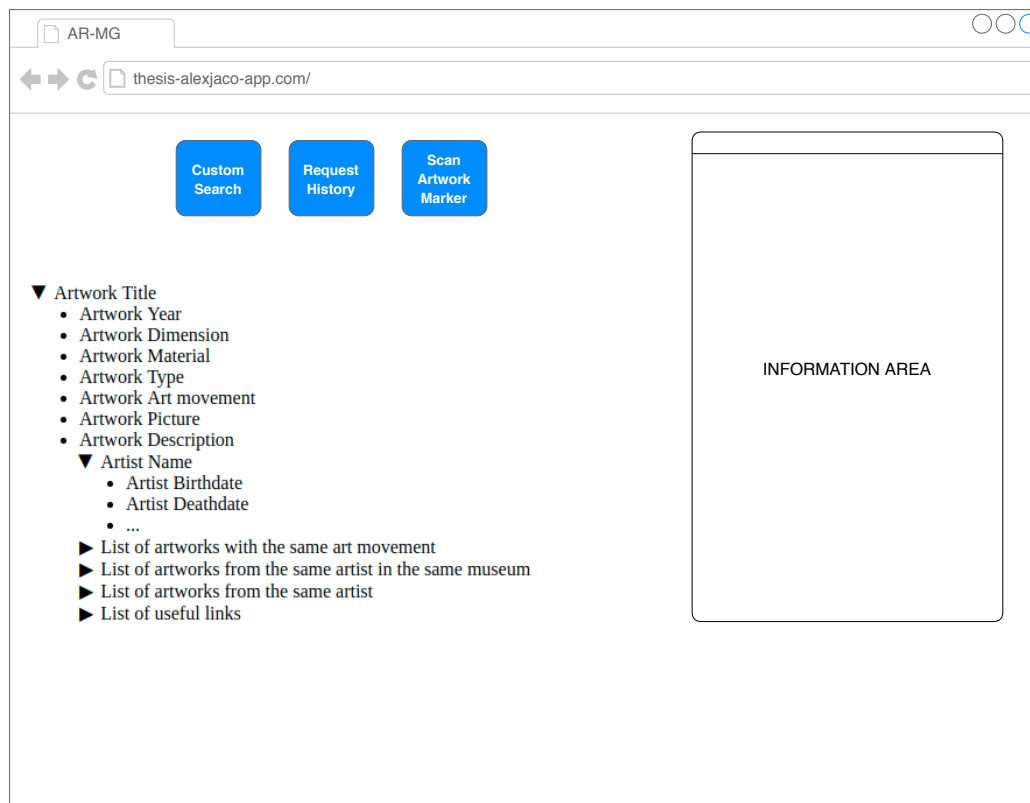


Figure 4.3: Mockup of Data Visualisation User Interface

4.3.3 Custom Search User Interface

The search interface will be simple and minimalistic. There will be just a search bar and a zone to display the results of the search in a datatable.

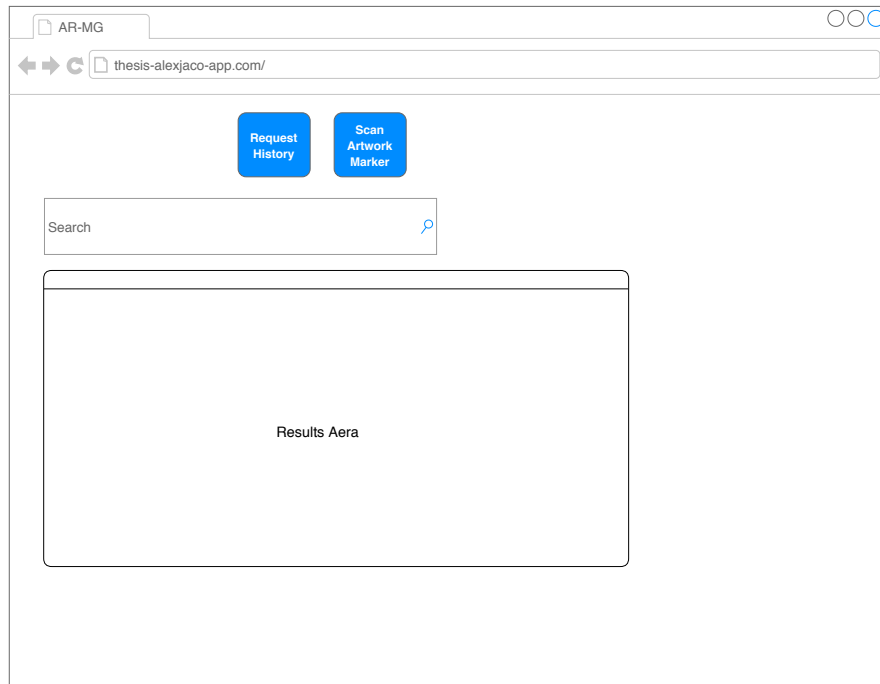


Figure 4.4: Mockup of Custom Search User Interface

In conclusion for our final functional prototype, the application will have the interfaces previously mentioned as well as simple login and register interfaces. The interaction with our user interface will therefore be convenient and intuitive for visitors. When a visitor wants to use our application, they first log in and then can scan the marker identifying an artwork. Once it is done and the request is processed by our server, the visitor can interact with the different user interfaces presented above.

The interaction with our web application is done by simply pointing to the icons and to click on the pointed icon. The same can be done to enter during a personalised search. For the interaction with the museum environment, we have chosen the use of ArUco² markers, which contain the identifier of an artwork. The markers will help us with the positioning of the virtual elements.

²ArUco: <https://www.uco.es/investiga/grupos/ava/node/26>

4.4 Application Functionalities

Our application has the following features:

- See basic and advanced artwork information
- See basic and advanced artist information
- See a visualisation of the data related to an artwork.
- Do a customised search
- Consult requests history

In the future, we can think about adding more features, using other means to engage the user even more. This is described in more detail in **Chapter 7**. Having the following features, different user scenarios could be found. In our application, we can see five user scenarios: basic and advanced data exploration, artwork data graph exploration, personalised search and request history.

5

Implementation

In this chapter, we present all the technical details of our application as well as the languages and frameworks used for the implementation. We also talk about the problems encountered during the implementation of the different parts of our application.

5.1 Solution Overview

From our theoretical solution to our practical solution, we have entirely implemented what we described in **Chapter 4**. As mentioned in **Figure 4.1**, our architecture is composed of two important components: the client application and the server.

The client side, which is executed from a web browser running on a tablet that we have chosen as support, is composed mainly of two components. The first component is the user interface where the data received are processed and displayed by the client service. The second one is the client service which allows us to manage the requests and data received from the server in order to display them to the visitor via the user interface. The language used on the client side are HTML, CSS and JavaScript.

Originally we thought that we would use the ARCore¹ and WebXR² frameworks to support augmented reality, but there were some issues that caused us to look for other frameworks. We will discuss this with all the other issues encountered during the development of the client side. Finally, we found the A-Frame³ and the AR.js⁴ frameworks to implement the augmented reality part. Further, in order to detect the artwork and place the information in the best way, we used ArUco markers.

On the other side, we have our server, which runs on a machine managed by Heroku⁵. Therefore, this allows us to make our application available online. We have chosen that our server runs under Python, because it is an easy-to-use language. As a web framework to deploy our website, we used Flask⁶.

If someone wants to try our application, they can find the full application code on our Gitlab repository⁷. In addition, there is a step-by-step installation guide available in **Appendix A.3**.

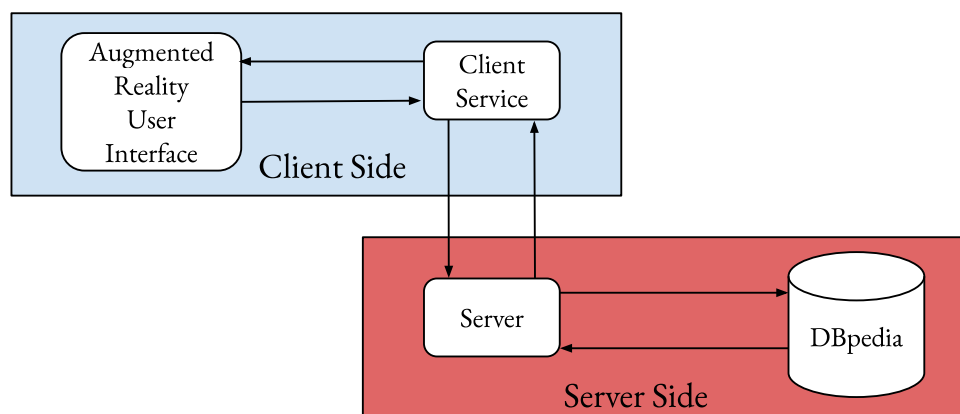


Figure 5.1: General overview about application architecture

¹ARCore documentation: <https://developers.google.com/ar/reference>

²WebXR documentation: <https://www.w3.org/TR/webxr/>

³A-Frame documentation: <https://aframe.io/docs/1.0.0/introduction/>

⁴AR.js documentation: <https://ar-js-org.github.io/AR.js-Docs/>

⁵Heroku documentation: [urlhttps://devcenter.heroku.com/categories/reference](https://devcenter.heroku.com/categories/reference)

⁶Flask documentation: <https://flask.palletsprojects.com/en/1.1.x/>

⁷Code:https://gitlab.com/AlexJacobs95/master_thesis_app_alexjaco

5.2 Server Side

As explained in the previous **Section 5.1**, our server is hosted on Heroku. The server allows us to handle requests from the client. The main requests that the server will receive concern retrieving information from the DBpedia semantic database. In order to put all this in place, there are different technical requirements for the server:

- Python 3.8⁸
- Git⁹
- Flask
- PostgreSQL 12¹⁰
- Pillow¹¹
- SPARQLWrapper¹²
- Heroku

5.2.1 Heroku & Flask

Heroku is a cloud platform, it allows different applications to be deployed in different programming languages. It uses Amazon Web Services to deploy applications built on Heroku. Applications are launched using dynos, which is a virtual machine that can be active or inactive depending on the use of the application. In addition, we chose this platform because it is designed for developers, easy to use and configure.

Heroku was simple to configure and we first followed the guidelines proposed by the platform for the setup on our local machine. Then, in order to have a perfect configuration, we followed another tutorial¹³ which allowed us to configure Heroku with our Flask server and the PostgreSQL database. For the deployment of the application, every time we push our changes to Heroku, it updates our prototype.

In addition to Heroku for the deployment and hosting of our application, we used Flask. Flask is a web framework to manage our website. It is a

⁸Python documentation: <https://docs.python.org/3/>

⁹Git documentation: <https://git-scm.com/doc>

¹⁰PostgreSQL documentation: <https://www.postgresql.org/docs/>

¹¹Pillow documentation: <https://pillow.readthedocs.io/en/stable/>

¹²SPARQLWrapper documentation: <https://sparqlwrapper.readthedocs.io/en/stable/index.html>

¹³<https://realpython.com/flask-by-example-part-1-project-setup/#heroku-setup>

framework that helps us to create a web server in Python. It is a quite simple framework. Concerning the configuration of our server, we just followed the basic tutorial provided by the developers of the framework. Whenever our client side sends a request, this request is processed by our Flask server by the right method.

In our application, in order to be able to respond to specific requests, it was necessary to develop a database. To develop the database, we chose to use PostgreSQL, because this type of database was simpler to use and has a Heroku compatible extension. PostgreSQL is an open source relational database management system. Our database contains five tables: `User(username, password)`, `ArtworkMakerId(identifier, artworkName, artMovement, artworkPresence)`, `ArtworkRequestHistory(artworkName, username)` and `CustomSearchHistory(search, username, parameters)`. These tables are mainly used to keep track of actions using our website and also to have a mapping between pre-selected artwork names and their identifier with the style of the artwork. As said, our database has a `User` table which contains user information. The password of a user is encrypted using a basic encryption method of Python. Also in the table `ArtworkMakerId`, we putted a flag `artworkPresence` to be able to know if the scanned artwork is presented or not in the museum.

For implementation, and user evaluation purposes, we have inserted in our database artworks selected by ourselves. We selected different types of artwork. For the selected artworks, we assigned them an identification number, and we specified the art movement (see **Subsection 5.2.3**).

- Mona Lisa, Leonardo Da Vinci
- Campbell's Soup Cans, Andy Warhol
- Christ of Saint John, Salvador Dalí
- Guernica (Picasso), Pablo Picasso
- The Weeping Woman, Pablo Picasso
- The Starry Night, Vincent van Gogh
- The Night Watch, Rembrandt
- The Ghost of Vermeer of Delft Which Can Be Used As a Table, Salvador Dalí
- Whistler's Mother, James Abbott McNeill Whistler
- Pietà (Michelangelo), Michelangelo
- David (Michelangelo), Michelangelo
- The Thinker, Auguste Rodin

5.2.2 SPARQL Queries

To make our queries, we use the SPARQL language. These queries are forwarded to the DBpedia database. SPARQL is an RDF query language, which allows us to retrieve data from semantic databases or other data sources that have an RDF structure. DBpedia is a semantic database whose purpose is to gather structured information that is available in Wikipedia with Linked Data between each resource. DBpedia knowledge is classified in a consistent ontology, exists in 125 languages and there are also connections to other linked datasets. All our SPARQL requests are made to the SPARQL endpoint of English version and French version DBpedia. To make these requests we make them in Python using a “SPARQLWrapper”, which allows us to execute from Python the requests on the different endpoints.

In the personalised search, we again use SPARQL queries, in order to easily find what a visitor is looking for. We have defined categories to define the keywords entered. The categories are: art movement, artist, artwork, material, museum and type / technique. We let the possibility to the visitors indicate whether they want for their search a list of artworks related to the keyword search or just the DBpedia resources that match their keyword search.

The result of these queries is a JSON dictionary, which we process in order to retrieve all useful information. Once the processing is done, we send it back to the client also in the form of a JSON dictionary. There is an example of a query to retrieve the name of an artist, based on a specific artwork. In this example, we have removed all the Python variables used to create the query.

```
1
2 PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
3 PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
4 PREFIX dbo: <http://dbpedia.org/ontology/>
5 PREFIX owl: <http://www.w3.org/2002/07/owl#>
6 PREFIX prov: <http://www.w3.org/ns/prov#>
7 PREFIX foaf: <http://xmlns.com/foaf/0.1/>
8 PREFIX dbp: <http://dbpedia.org/property/>
9 PREFIX dbp-fr: <http://fr.dbpedia.org/property/>
10 PREFIX dct: <http://purl.org/dc/terms/>
11 PREFIX yago: <http://dbpedia.org/class/yago/>
12
13 SELECT Distinct ?author_name ?good_author_name
14 WHERE {
15   {
16     ?res rdf:type dbo:Artwork.
17   }
18   Union
19   {
20     ?res rdf:type yago:Creation103129123.
21   }
22   ?res rdfs:label "Mona Lisa"@en .
```

```
23   ?res dbo:author ?author.
24   ?author rdfs:label ?author_name.
25   OPTIONAL{
26     ?author dbo:wikiPageRedirects ?redirection.
27     ?redirection rdfs:label ?good_author_name.
28     FILTER (lang(?good_author_name) = 'en')
29   }
30   FILTER (lang(?author_name) = 'en')
31 }
```

Listing 5.1: SPARQL Query to search for artist name.

5.2.3 Issues Encountered

In the implementation of the server, we encountered some problems in the realisation of our queries to DBpedia. We have therefore solved these various problems by finding acceptable solutions.

The first problem we encountered was the fact that we had problems with the availability of data in the French and English versions of DBpedia. We might assume that data from one version to another version of DBpedia in different languages should be identical in its structure and content. Unfortunately, this is not the case between the two DBpedia versions used. Therefore, for an artwork if data is not available in one version of DBpedia, we look at the other version of DBpedia to find the missing information. If the information is not available in both DBpedia versions, we indicate it as missing. In addition, we also notice a standardisation issue in the data and how the data is recorded. There is sometimes a change of property name from one version to another and it is possible to have this also within the same version of DBpedia. Therefore, the only solution to such a problem was to make more general queries taking into account the different possibilities for the same information.

We also encountered problems about the impossibility of having the information and the fact of not being able to provide the information, because it is impossible to certify that the information are correct concerning the artwork. Consequently, we have encountered the following problems:

- The inability to retrieve information about reinterpretations and replicas of an artwork directly from the artwork or indirectly from another DBpedia resource. This information was one of the predefined information that had been selected from the survey results (see **Section 3.1**). Therefore, we decided to replace this information with the dimensions of the artwork that ranked just behind in our survey results.

- Another problem we encountered in the information directly available when we query an artwork is the fact that we cannot be sure of the style of the artwork. On the other hand, we can deduce the style of the artwork by looking at the art movement of the artist linked to the artwork. Therefore, we have taken as an assumption to solve our problem that if there is one art movement listed then we can think that the artwork is of this style. On the other hands if the artist has more than one style listed, we cannot decide which style the artwork is and we specify this to the visitor.
- By having highlighted the previous problem, it has become difficult to really determine the list of artworks with the same style. We therefore decided to replace this information with another information which is a list of artworks that have been made in the same century. This information was the result that appeared just behind the style in our survey.

We found another problem while developing the customised search. The problem was a timeout when queries are made outside the SPARQL DBpedia endpoint. If we made too general queries, i.e. searching for resources that included the keywords we were looking for, we would get a timeout. But the same query tested directly on the SPARQL DBpedia endpoint was working perfectly. To solve this, we defined predefined types to represent the keywords entered into the search bar. This solution solved the timeout problems. With this solution, we thought to allow the possibility to specify the type of keywords entered into the search bar. As we highlighted with our first attempts to look for a resource with only matching text, we again experienced timeouts or other limitations of DBpedia. The limitations are that the maximum execution time was exceeded if the query was too general and that cannot be changed, since those are parameters specific to DBpedia.

The last problem we were able to discover was a timeout problem initiated by our Heroku host. It happens if a request lasts more than 30 seconds, Heroku throws an error “H12”. We investigated and found that this kind of error was partly due to the fact that we were requesting all the data for artwork in a single request. The problem was also partly due to the fact that our application was deployed on Heroku servers located in America. Thus, we solved this problem in two different manners. The first manners that we implemented was to redeploy our application on Heroku servers located in Europe to reduce the execution time. The second manners that we implemented was instead of doing all the requests at once, the server should execute a request to get some of the basic information and sends it back to

the client. Once the result of the request is retrieved by the client, we make a POST HTTP request from the client side for each missing information. By doing this, we never had a Heroku's H12 timeout anymore.

5.3 Client Side

As explained in the overview of our application, the client side is composed of several parts including the user interface and the client service, as shown in **Figure 5.1**. In our application, we have a total of five user interfaces. Three are the main interfaces and the most important of these three interfaces is the augmented reality interface. The interfaces of our application are the login and registration form, the augmented reality interface, the interface to view all data related to an artwork, the interface to perform personalised searches and an interface to view the requests that have already been made using the application. The client service is a JavaScript code executed in real time in order to process the visitor's actions. It also processes the data send to the server and returned to the client in order to be processed and update the user interface. In order to put all the user interface in place as described in **Chapter 4**, These are the different technical requirements of our client side:

- HTML
- CSS
- JavaScript
- A-Frame
- AR.js
- ArUco markers
- Blender to create 3D models

5.3.1 ArUco Marker

ArUco markers are fiducials markers. ArUco markers are useful for object positioning and camera calibration. They have been used for a long time in augmented reality. Those are 2D markers composed of black and white pixels in the shape of a grid. Each ArUco marker has a unique pattern that corresponds to a number. In our application, we use these markers to detect which artwork is by assigning a number that identifies a marker and the name of an artwork in our PostgreSQL database.

Therefore, when a marker is detected, we can easily retrieve the corresponding artwork. To achieve this, we used JS-Aruco¹⁴, a JavaScript library based on the ArUco library. This library allows us to easily access the ArUco library and the OpenCv methods used in it.

5.3.2 Augmented Reality User Interface

As already said above, we used the A-Frame and AR.js frameworks to implement augmented reality into our application. A-Frame is an open source framework for bringing virtual reality into web browsers, based on HTML. AR.js is a library for bringing augmented reality to the web. This library allows image tracking, marker tracking and localisation. It is a multi-platform library and is really easy to use because it is a wrapper of different frameworks allowing augmented reality. This library is based on A-Frame and Three.js.

Therefore, our augmented reality interface consists of the components shown in **Figure 4.2**. The different buttons are 3D models created using Blender. Concerning the text areas for most of them, those are created on the fly using an A-Frame component. But for the artwork and artist abstracts, these are pictures created in real time by our server. Because during the implementation, we noticed that this resulted in very large text areas.

Moreover, for the placement of the objects, this is very simple because we base ourselves in the position of the marker. Above this marker, we present a picture of the artwork for easy development. Besides, in a real use, the use of an image as artwork representation is only necessary if the artwork is not present for restoration or if a visitor clicks on artwork name linked to the scanned artwork. The artwork presence will be known by checking the corresponding flag as mentioned in **Section 5.2**. Also, the positioning of the object in a real use in a museum has to be configured for each artwork.

When a visitor clicks on one of the buttons, depending on what it does, they can either be redirected to a new interface or have access to a set of functionality related to the clicked button. On the other hand, if the visitor interacts by clicking on the name of an artwork, then the augmented reality interface will be updated with the available data about the clicked artwork. But if the interaction is done on a website URL, the visitor is redirected to the website. To recapitulate, when the artwork is identified using an ArUco

¹⁴JS-Aruco: <https://github.com/jcmellado/js-aruco>

marker, our application will show the user a panel of buttons allowing different actions. We also show the title of the artwork, the name of the author and the year of creation just below the artwork.

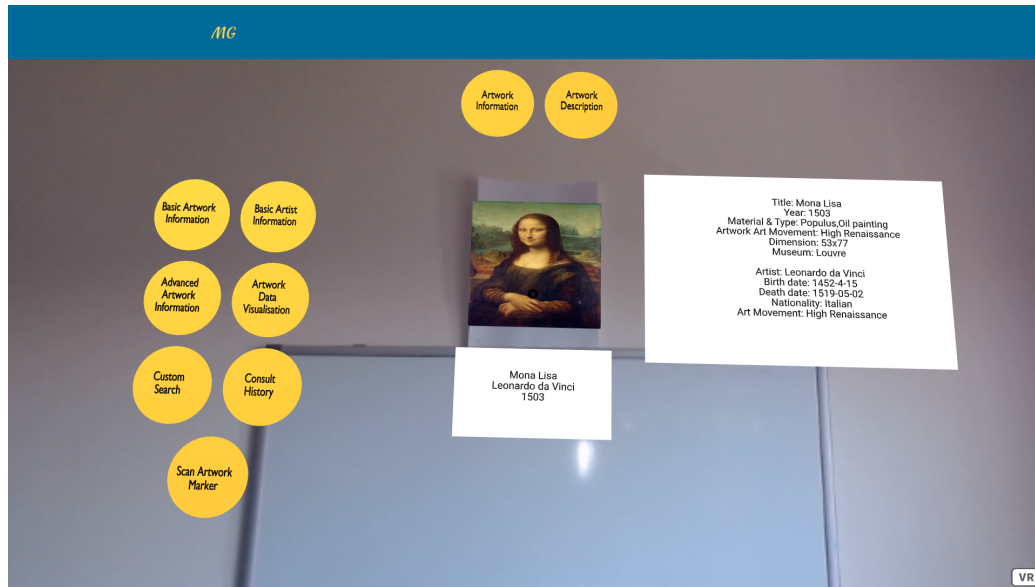


Figure 5.2: Augmented Reality User Interface Screenshot

5.3.3 Artwork Data Visualisation User Interface

The interface allows the visualisation of the data related to an artwork as well as what is indirectly connected to it. The interface has been realised using simple HTML, CSS and JavaScript in a 2D version of a “Tree View”. We did this to have a simple interaction and pleasant navigation. Moreover, we chose this visualisation because with augmented reality this would have been complicated and not all frameworks offered the interface that we were looking for in an augmented way. Therefore, we had limitations in the interaction and navigation of the data.

As illustrated in **Figure 5.3**, our interface is a good representation of what was described in **Chapter 4** in **Figure 4.3**. To achieve such a representation, the content of the view is created in real time using the server responses and to display artwork, links or people lists we decided to use datatables to avoid having extended lists. Concerning the artwork and artist descriptions, these are text areas. For the pictures, it is a simple image con-

tainer with an embedded internet link representing the picture. Concerning the interaction, if the visitor clicks on a blue link the view is updated or the visitor is redirected to new interface or new web page according to the link.

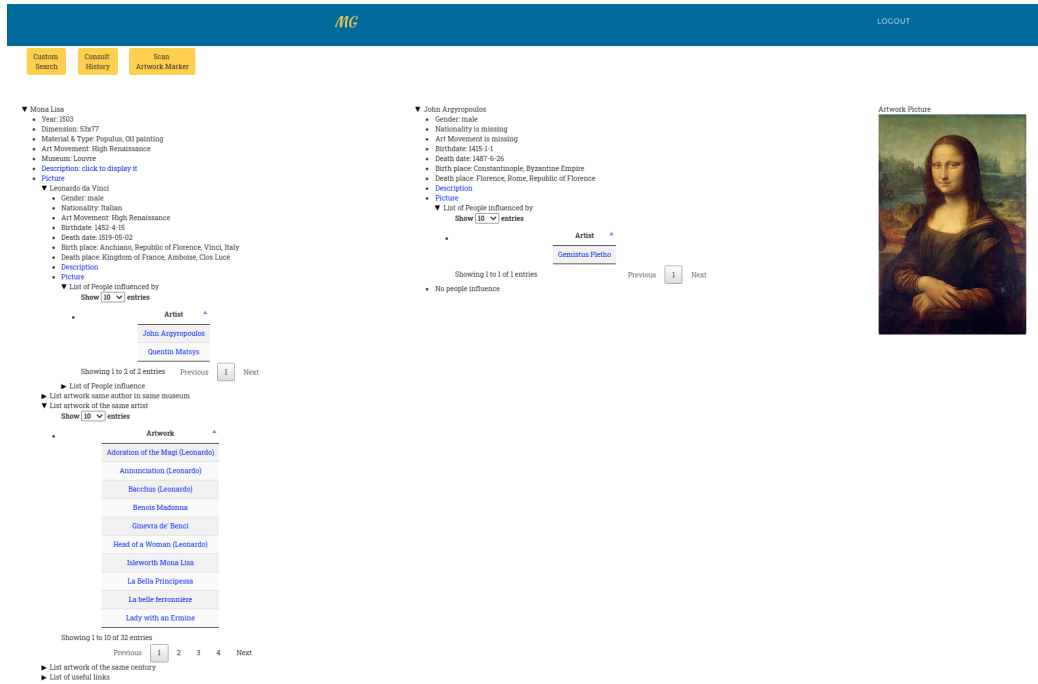


Figure 5.3: Artwork Data Visualisation User Interface Screenshot

5.3.4 Custom Search User Interface

Just like the interface to visualise the data related to an artwork, we have chosen a normal interface 100% composed of HTML, CSS and JavaScript. Once a request has been made in this interface, a visitor can visualise the result of their search in a datatable. For the same reasons, as mentioned before, we did not choose to do this in augmented reality. About interaction, the visitor can click on the resource link for each result and will be redirected to the linked DBpedia page.

On the other hand, we have adapted the design of our interface from what we had previously proposed in **Figure 4.4**. We have added checkboxes to specify the type of keywords and if they want a list of artworks related to their search. We made these changes as a direct response to the related issue we reported in **Subsection 5.2.3**.

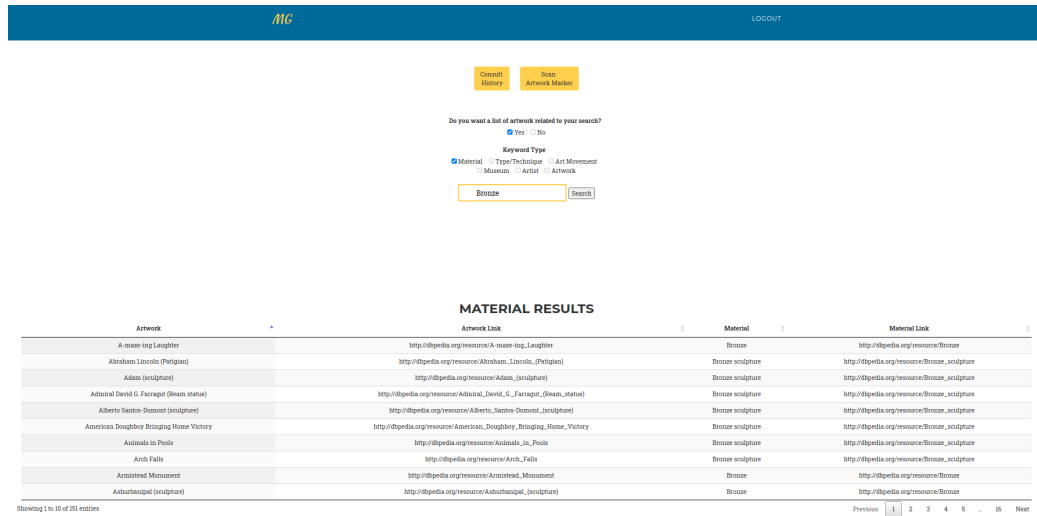


Figure 5.4: Custom Search User Interface Screenshot

5.3.5 Request History User Interface

As for the two interfaces above, we also used a framework that allows to create datatables with the content of the searches or scanned artworks by a visitor. To do this, we again used HTML, CSS and JavaScript to process the data coming from the server. In this interface, we considered it convenient not to use augmented reality because it would not bring anything to the user. Concerning the interactions, if the visitor clicks on one of these searches, they will be redirected either to the search page with the content of the search performed or to the 2D visualisation interface of the data related to the artwork and what is indirectly related to it.

5.3.6 Issues Encountered

Concerning the problems encountered, we encountered only one major problem, this problem concerns the augmented reality interface due to the choice of the framework considered in **Chapter 4**. We had considered using WebXR API, it is a framework that allows to realise interfaces of virtual reality as well as augmented reality. It comes to replace what already existed in virtual reality in browsers using WebVR. The problem was that it is a technology that can only be developed on certain devices and on certain versions of web browsers. Moreover, if the application was developed on a browser version that is WebXR compatible, it could not work if the device used is simply not

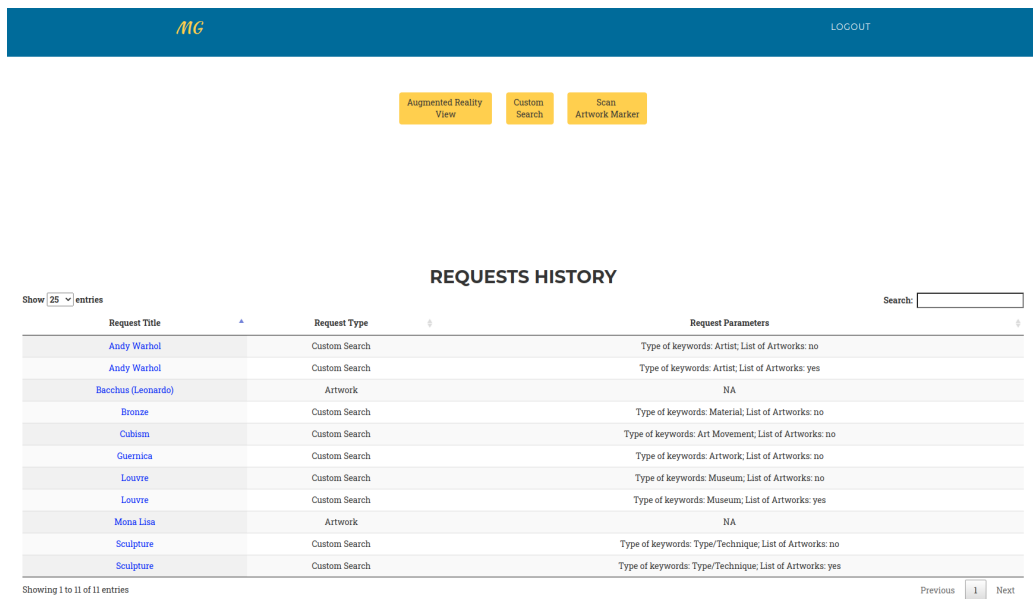


Figure 5.5: Request History User Interface Screenshot

compatible either This was a problem that we encountered during tests of the technology.

Another concern encountered with this technology, as it is still quite recent and still under discussions and development between developers. It is difficult to really capture what is feasible in augmented reality, the limitations that can result from using this technology and also what cannot be achieved with it.

5.4 Testing

Throughout the development, the testing of our application was done in different ways. We independently tested each component of our application. The client side of the application has been tested mainly by using the application like an end user would do it. We did this to see if the application reacts well to our interactions with the different user interfaces and functionalities. We also tested the application in order to see if the real-time processing performed by the client service did not cause any problems using the developer's console of a browser. The real test as an end user allowed us to improve some interaction, functionalities as well as the content and the layout of the different user interfaces.

For the server side, we mainly tested the requests made by our server to the DBpedia endpoint, the internal requests to our database, and the on-the-fly processing of the requested data. We mainly used the debugging tool provided by the Pycharm IDE. For the SPARQL queries to the DBpedia endpoint, we tested all of them one by one directly on the endpoint, as well as from our server using SPARQLWrapper. The fact that we did these different tests, allowed us to improve our server. To conclude, the testing of our application throughout its development allowed us to detect some glitches we mentioned in the previous **Subsection 5.2.3** and **Subsection 5.3.6**.

6

Use Case and Evaluation

In this chapter, we present a basic use case of our application. In addition, we also present a user interface and user experience study conducted with potential end-users of our application. We conducted this study in order to be able to measure its potential, efficiency and usability.

6.1 Use Case

Our application is designed to make a visit to the museum more enjoyable and more flexible access to other information about an artwork. In the context of a museum visit, our application can have various benefits. As mentioned **Chapter 4**, our application has different functionalities that lead to different user scenarios.

6.1.1 Basic & Advanced Information Exploration

In this scenario, we represent a visitor walking around and looking at the artworks. They would like more information about the subjects of a particular work of art. The visitor is already connected to the application and scans the marker associated with the artwork. Once the interface is returned to the visitor, they can click on the various icons available on the left-hand side of the artwork to display basic and advanced details.

Figure 6.1 presents what a visitor can see if they scan the artwork marker id related to Mona Lisa, after interacting with the button basic artwork information. In this interface, the visitor can see the artwork through the device with its augmented reality part around it.

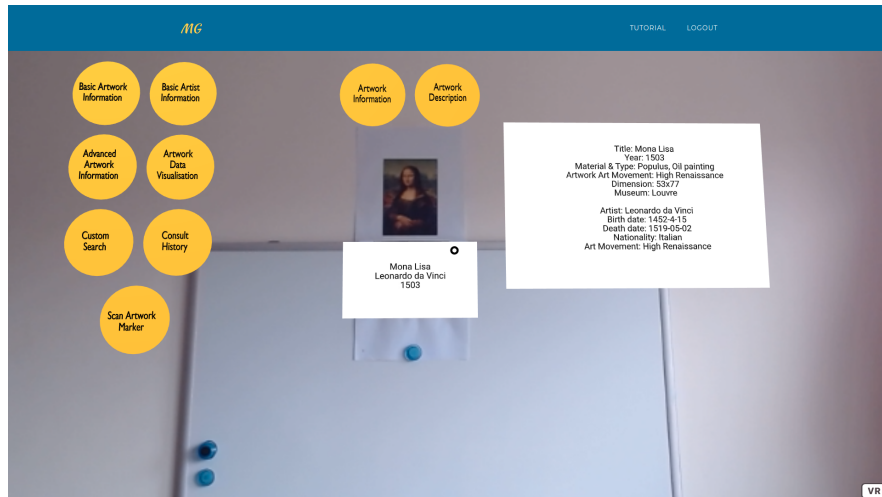


Figure 6.1: Example of AR User Interface with basic information about Mona Lisa

Figure 6.2 illustrates what a visitor can see, if they request the basic artist information of Mona Lisa.

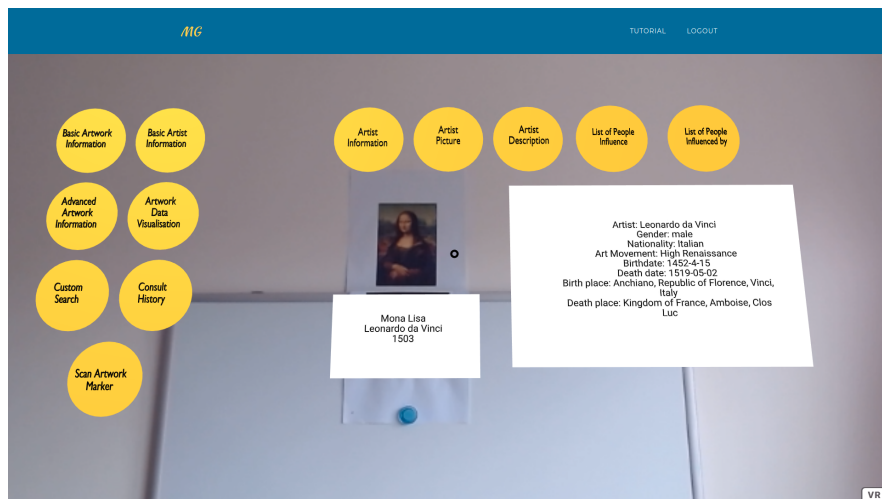


Figure 6.2: Example of AR User Interface with basic information about Leonardo Da Vinci

Figure 6.3 shows the augmented reality interface with a picture of Leonardo Da Vinci after the visitor request it by clicking on the corresponding button.

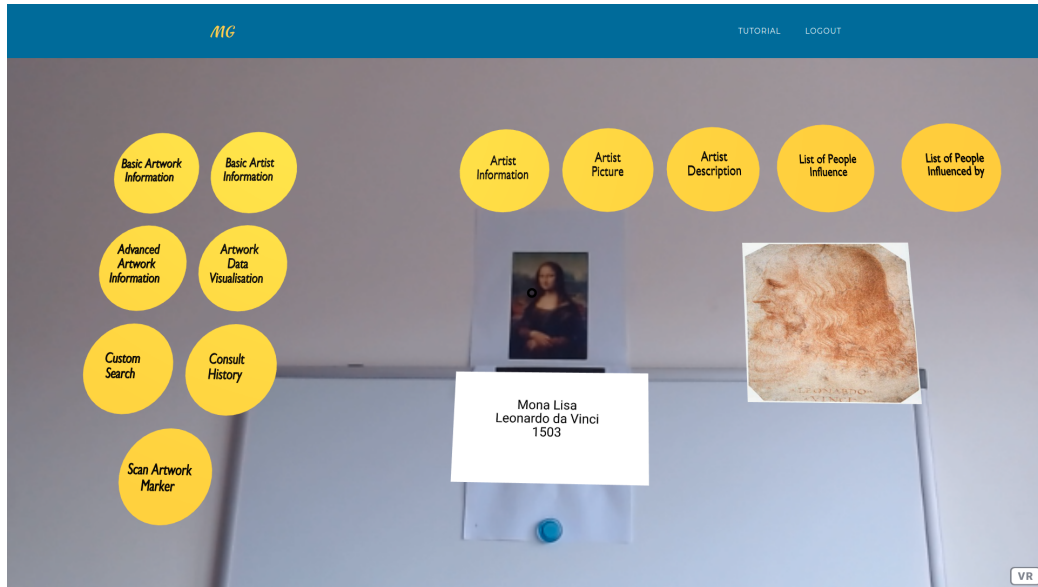


Figure 6.3: Example of AR User Interface with the picture of Leonardo Da Vinci

From there, a visitor can also switch to other features by using the buttons on the left-hand side of the artworks.

6.1.2 Data Visualisation Exploration

In this functionality scenario, a visitor who has already scanned an artwork marker, they can navigate freely through our “Tree View”, opening and closing the sub-menus as they wish. If a visitor clicks on the link related to another artwork, it will refresh the interface and display a new “Tree View” based on data of the selected artwork.

Figure 6.4 shows what the visitor have when they scanned the artwork marker related to “Campbell’s Soup Cans”. The interface displays only the basic information if the visitor clicks on the artwork name. Also, **Figure 6.5** illustrates what the visitor will get when they click on the name of an artist who influenced Andy Warhol. As in the previous functionality scenario, the visitor can switch to the other features of the user interface.

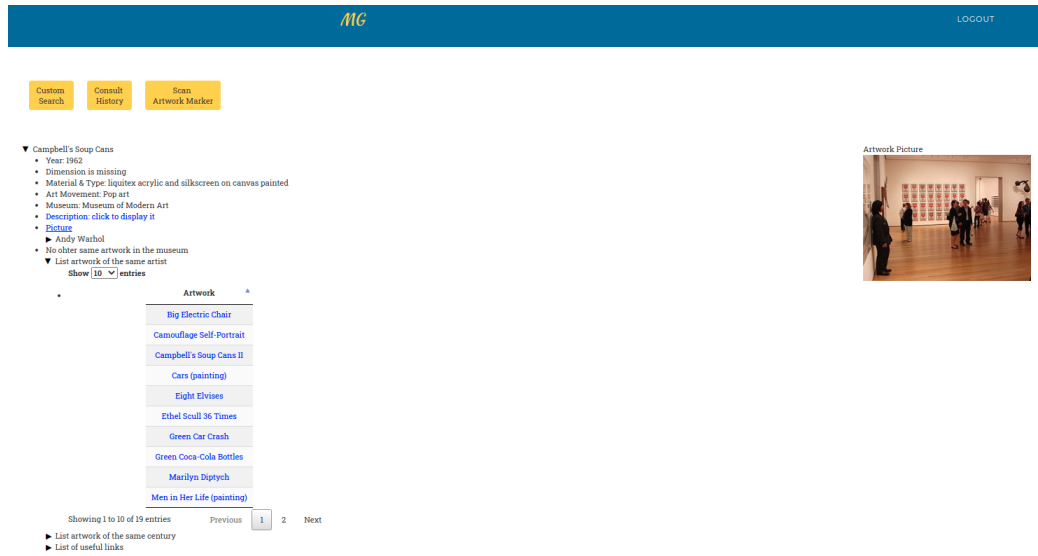


Figure 6.4: Example of artwork data visualisation with Mona Lisa information

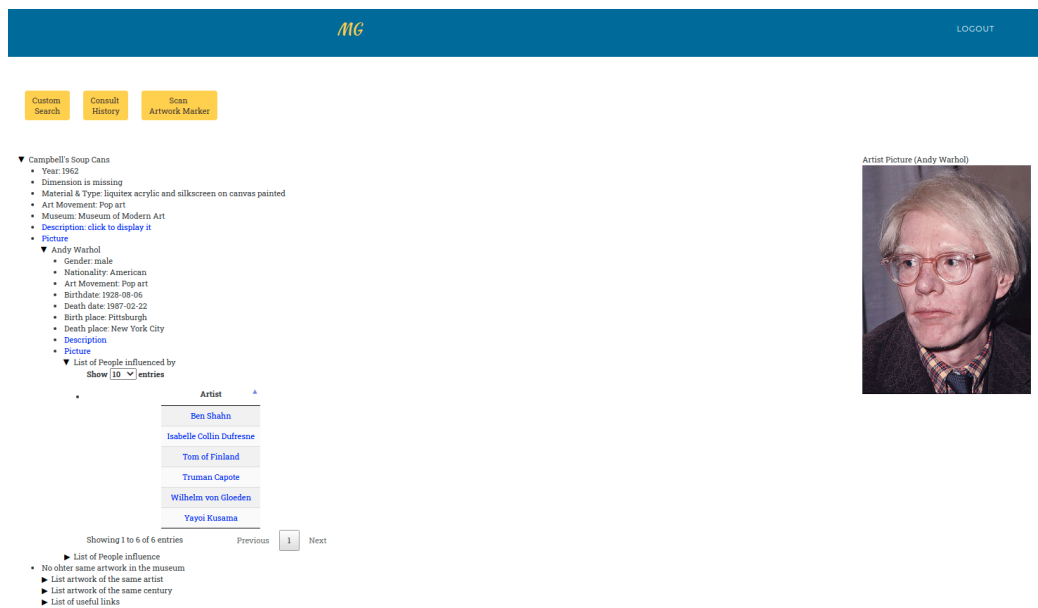
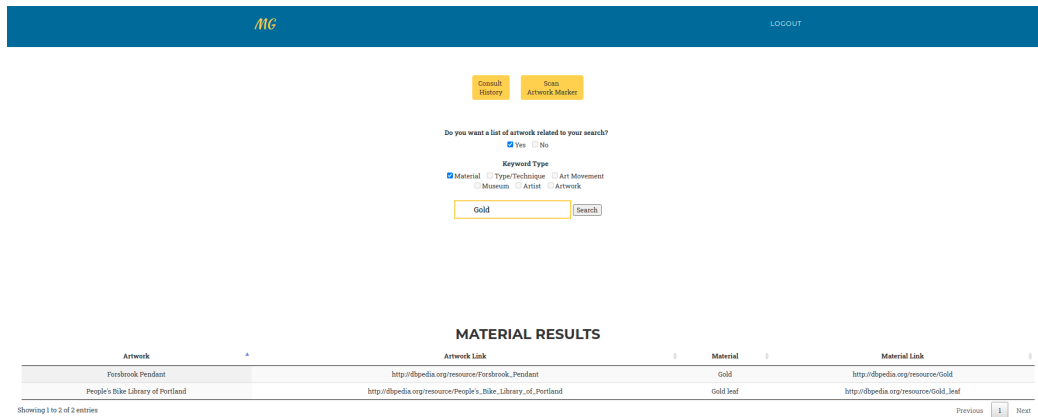


Figure 6.5: Example of artwork data visualisation user interface with Andy Warhol information

6.1.3 Customised Search

In the context of a personalised search, a visitor can choose to have the result with a list of artworks related to his search. In addition, a visitor can tell the type of his personalised search. Once the search is completed, the visitor can see the result in a datatable. Here are the results of personalised search on gold as a material with a list of artworks (**Figure 6.6**) and on museums whose name contains “national gallery” (**Figure 6.7**). The visitor can also do customised searches outside the museum.

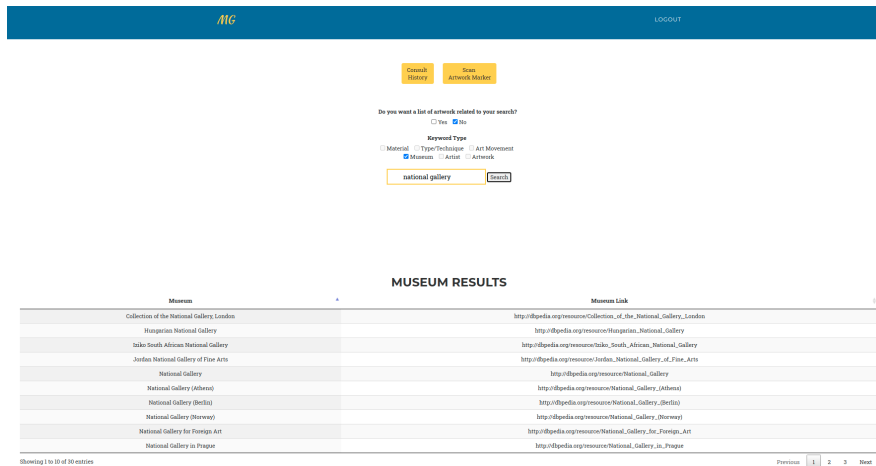


The screenshot shows the MG search interface. At the top, there is a blue header with the MG logo and a LOGOUT button. Below the header, there are two buttons: 'Consult History' and 'Save Artwork Marker'. A form asks 'Do you want a list of artwork related to your search?' with a 'Yes' radio button selected. Under 'Keyword Type', 'Material' is selected. The search input field contains 'Gold' and a 'Search' button is next to it. Below the search form, the results are displayed in a table titled 'MATERIAL RESULTS'.

Artwork	Artwork Link	Material	Material Link
Forsbrook Pendant	http://dpeida.org/resource/Forsbrook_Pendant	Gold	http://dpeida.org/resource/Gold
People's Bike Library of Portland	http://dpeida.org/resource/People's_Bike_Library_of_Portland	Gold leaf	http://dpeida.org/resource/Gold_Leaf

Showing 1 to 2 of 2 entries

Figure 6.6: Example of custom search with keyword gold and material as keyword type



The screenshot shows the MG search interface. At the top, there is a blue header with the MG logo and a LOGOUT button. Below the header, there are two buttons: 'Consult History' and 'Save Artwork Marker'. A form asks 'Do you want a list of artwork related to your search?' with a 'Yes' radio button selected. Under 'Keyword Type', 'Museum' is selected. The search input field contains 'national gallery' and a 'Search' button is next to it. Below the search form, the results are displayed in a table titled 'MUSEUM RESULTS'.

Museum	Museum Link
Collection of the National Gallery, London	http://dpeida.org/resource/Collection_of_the_National_Gallery_London
Hungarian National Gallery	http://dpeida.org/resource/Hungarian_National_Gallery
Isle de Seville African National Gallery	http://dpeida.org/resource/Isle_Seville_African_National_Gallery
Jordan National Gallery of Fine Arts	http://dpeida.org/resource/Jordan_National_Gallery_of_Fine_Arts
National Gallery	http://dpeida.org/resource/National_Gallery
National Gallery (Athens)	http://dpeida.org/resource/National_Gallery_Athens
National Gallery (Berlin)	http://dpeida.org/resource/National_Gallery_Berlin
National Gallery (Bonn)	http://dpeida.org/resource/National_Gallery_Bonn
National Gallery for Foreign Art	http://dpeida.org/resource/National_Gallery_for_Foreign_Art
National Gallery in Prague	http://dpeida.org/resource/National_Gallery_in_Prague

Showing 1 to 10 of 10 entries

Figure 6.7: Example of custom search with keyword national gallery and museum as keyword type

6.1.4 Requests History

For this feature, the visitor can view all the artworks that have already been scanned and all the custom searches already made. In the datatable, the visitor can see what type of requests that have been done. Depending on the type of request, the data displayed are different as well as the interaction. Like the custom search, a visitor can access both inside or outside the museum if they wish. **Figure 6.8** shows what a visitor gets as history when they have made several requests earlier.

Request Title	Request Type	Request Parameters
Campbell's Soup Cans	Artwork	NA
Gold	Custom Search	Type of keywords: Material; List of Artworks: yes
Mona Lisa	Artwork	NA
national gallery	Custom Search	Type of keywords: Material; List of Artworks: no
national gallery	Custom Search	Type of keywords: Museum; List of Artworks: no

Figure 6.8: Example of user interface with all requests history made

6.2 Evaluation

The evaluation of our application is done in a manner to get the users' opinion on the interface and also their experiences. For the evaluation of the user experience, we used the short version of the User Experience Questionnaire (UEQ)¹. This questionnaire will allow us to measure a user's impression of our application by looking at usability aspects. With this questionnaire, we will be able to have measures about two qualities:

- pragmatic quality: this quality relates to functionality and practicality of our user interfaces.

¹<https://www.ueq-online.org/>

- hedonic quality: this quality relates to the comfort of our user interfaces, it helps to know if the user interface is appealing, avoid discomfort and boredom.

To gather their opinions on the user interface, we conducted a survey on each user interface that our application has. In this survey, we asked their opinions on the whole application via the short version of the UEQ and of the data used in general as well as individually for artwork and artist. These are the general questions about our application.

- Overall reaction to the application (based on the short version of UEQ)
 - Item 1: Obstructive - 1|2|3|4|5|6|7 - Supportive
 - Item 2: Complicated - 1|2|3|4|5|6|7 - Easy
 - Item 3: Inefficient - 1|2|3|4|5|6|7 - Efficient
 - Item 4: Confusing - 1|2|3|4|5|6|7 - Clear
 - Item 5: Boring - 1|2|3|4|5|6|7 - Exiting
 - Item 6: Not interesting - 1|2|3|4|5|6|7 - Interesting
 - Item 7: Conventional - 1|2|3|4|5|6|7 - Inventive
 - Item 8: Usual - 1|2|3|4|5|6|7 - Leading edge
- Do you have some recommendations?

These are the questions commonly to each interface:

- Is the interface comfortable?
 - Terrible - 1|2|3|4|5|6|7 - Wonderful
- Is the interface easy to use and to understand?
 - Difficult - 1|2|3|4|5|6|7 - Easy
- Do you have some recommendations?

These are the specific questions about Artwork Data Visualisation User Interface.

- Does the interface display the data in the best possible way?
 - Confusing - 1|2|3|4|5|6|7 - Clear
- Does the interface facilitate data exploration?
 - Impractical - 1|2|3|4|5|6|7 - Practical

These are the specific questions about Custom Search User Interface.

- Does the interface display the search result in the best possible way?
 - Confusing - 1|2|3|4|5|6|7 - Clear
- Does the search result presented meet your expectations?
 - Does not meet expectations - 1|2|3|4|5|6|7 - Meets expectations
- Do you have some recommendations?

These are the specific questions about Request History User Interface.

- Does the interface display the request history in the best possible way?
 - Confusing - 1|2|3|4|5|6|7 - Clear

These are the specific questions about the data used in our application.

- Does the overall data used meet your expectations?
 - Does not meet expectations - 1|2|3|4|5|6|7 - Meets expectations
- Was the data used correctly?
 - Not at all - 1|2|3|4|5|6|7 - Very much
- Does the artwork data used meet yours expectations?
 - Does not meet expectations - 1|2|3|4|5|6|7 - Meets expectations
- Does the artist data used meet yours expectations?
 - Does not meet expectations - 1|2|3|4|5|6|7 - Meets expectations

In our evaluation, 12 people took part in the study. In this study, participants used their own smartphones or tablets due to the health situation in Belgium at the time when the study was performed. We provided the testers with the different markers they could print to simulate artworks. Therefore, it is possible that some comments made during the evaluation about the design might reflected the use of other devices than the basic device that we recommended for our application.

6.2.1 Overall Reaction Results

To analyse the data gathered by our survey, we used the tool provided with the UEQ short version. This tool helps us to get the mean, standard deviation and variance, and the scale of pragmatic quality, hedonic quality and an overall scale too. We can interpret each mean value like that

- neutral evaluation if the mean is between -0.8 and 0.8
- positive evaluation if the mean is above 0.8
- negative evaluation otherwise if the mean is under -0.8

The range of the scale is between -3 which means horribly bad and $+3$ which means extremely good. With the two following figures, we can see that for all the aspect visitors have a positive evaluation. But in the case of the clarity of the application, it seems that some visitors evaluate this aspect has not clear, but in overall other visitors found the interface clear enough. A way to have better clarity would be to provide a training or add a “tutorial” page where the visitor can learn about how to use the application. We can see that both qualities have good scales and the overall scale is also good. Therefore, with all that, we can deduce that our application in general pleases the user and meets their expectations during a visit to a museum.

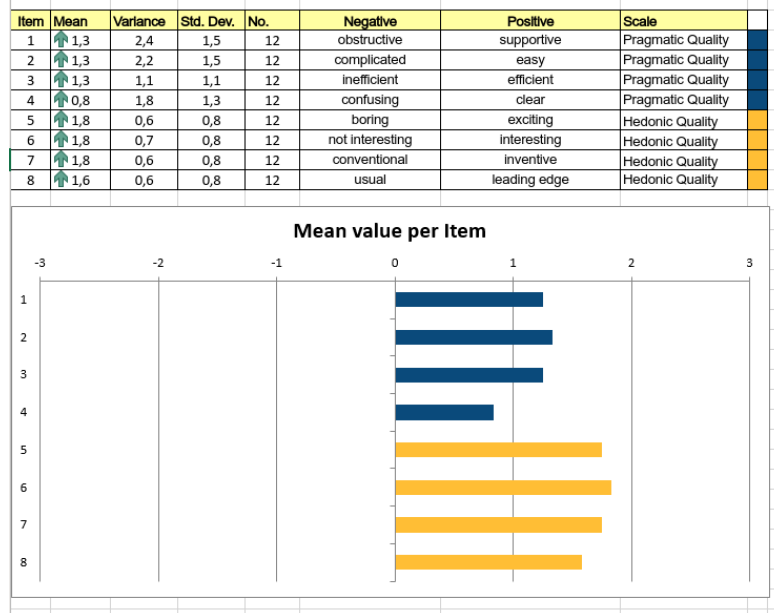


Figure 6.9: Table and Plot of mean value per item, result of Short UEQ

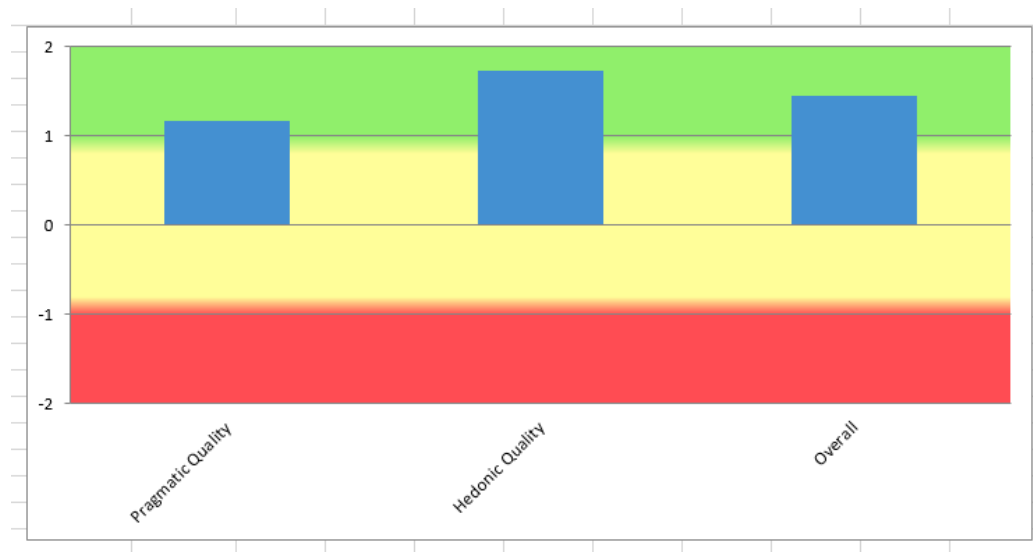


Figure 6.10: Short UEQ Scales

We also gave people the opportunity to leave a comment if they had recommendations for our solution in general. Only one person left a general recommendation. The other recommendations are more specific to the user interfaces, they will be addressed in the related sections below. The only general recommendation deals with having more explanation about the different features of the application and how to use them. This is a very good point. Moreover, with a remote experience context without the presence of researchers, this is clearly something that our application should offer. Therefore, we have designed pages that the visitor can use at any time.

6.2.2 Common User Interface Questions Results

As mentioned above, we asked people about our interfaces using questions. We had questions common to each interface, and below are the results represented using a histogram for each interface. The most common questions were:

- Is the interface comfortable?
- Is the interface easy to use and to understand?

Using the histograms shown in **Figures 6.11, 6.12, 6.13** and **6.14**, we can see that overall users have found our user interfaces comfortable, as well as easy to understand and easy-to-use. We can also say that the user interface

using augmented reality and the visualisation of artwork related data in the “Tree View” are two interfaces for which the users are a little less enthusiastic than the other interfaces. On the other hand, the users still appreciated those two interfaces. We can therefore establish with these different visualisations that the interface that is most successful is the requests’ history interface, the personalised search interface, the augmented reality interface and the data visualisation interface.

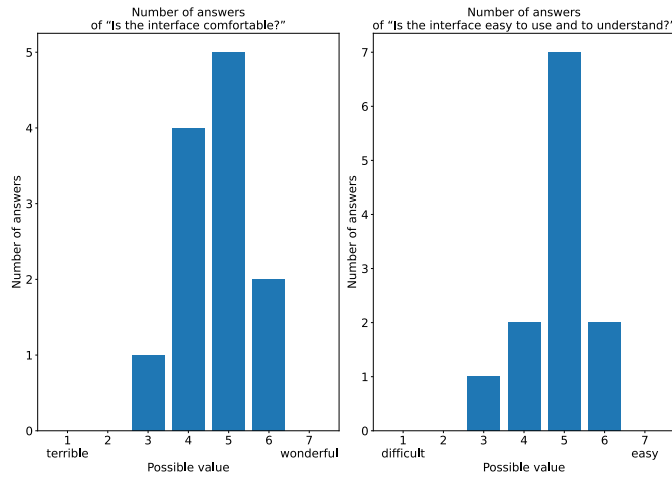


Figure 6.11: Plot of results for questions 1 and 2 about Augmented Reality User Interface

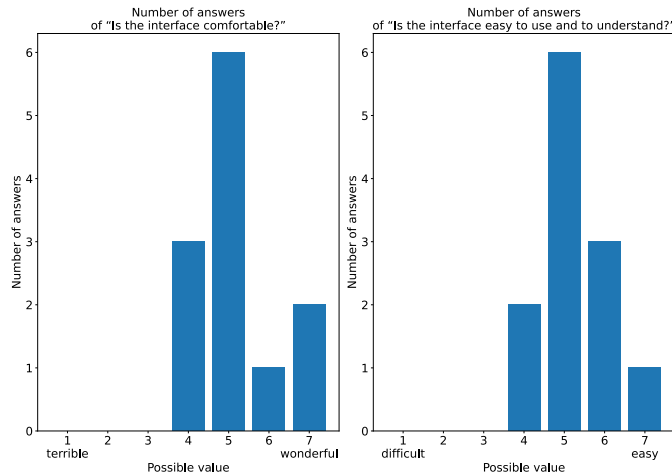


Figure 6.12: Plot of results for questions 1 and 2 about Artwork Data Visualisation User Interface

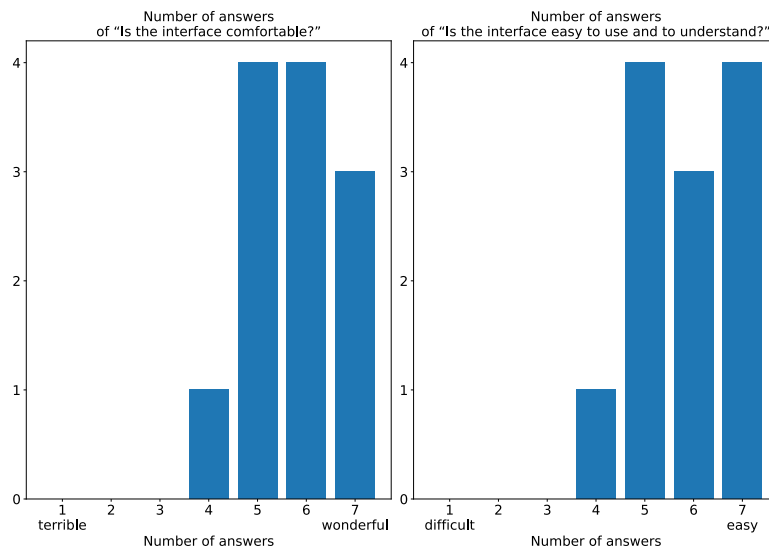


Figure 6.13: Plot of results for questions 1 and 2 about Custom Search User Interface

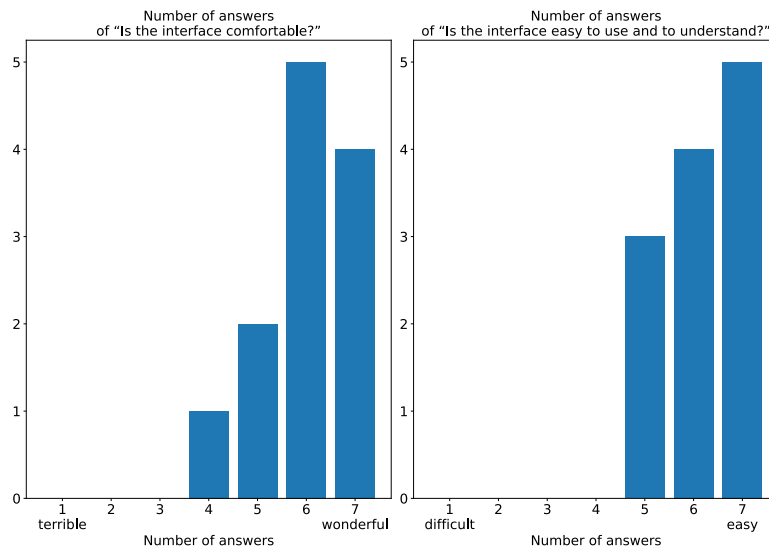


Figure 6.14: Plot of results for questions 1 and 2 about Requests History User Interface

6.2.3 Augmented Reality User Interface Evaluation Results

In the section of our survey related to augmented reality user interface, we had two questions, the results of those were presented above in the previous subsection. We also provided the opportunity for people to let recommendations on this interface. Most users did not find anything to say. However, four people left constructive recommendations. We had already discussed a recommendation for a page where the user could understand and how to use the different functionalities, this recommendation was also made by other users. Other recommendations are about the design of the user interface. For example, they recommend us to place the buttons a little closer to the artwork in order to make an easier access to the buttons and to interact with the buttons. They also recommend us to use additional markers, because the buttons are shaking more on some smartphones rather than on another device. Other markers can be used specifically for the buttons to prevent this shake effect. Also, it is reported that some users had problems with the display of pictures that were distorted. Regarding the distortion of some pictures, the pictures having this problem are the images that we create on the fly. Therefore, we know that they have a fixed width and variable height. Therewith, we can calculate a width-height ratio. With this ratio we use it to scale the image in our augmented reality interface. This last point can be added as an improvement in our application.

6.2.4 Artwork Data Visualisation User Interface Evaluation Results

About this part of the user interface, we asked people to know their impression about the information exploration and about the presentation of information. As shown in **Figure 6.15**, we can say that in overall the people found our user interface good in terms of data exploration and also about its design. In this part of the survey, nobody gave any recommendations, we can think that it is a consequence of doing a remote evaluation.

6.2.5 Custom Search User Interface Evaluation Results

Figure 6.16 illustrates the result for the question about the presentation of the search results and the quality of the search results found. We can again see that people are enthusiastic with the presentation of the search result in

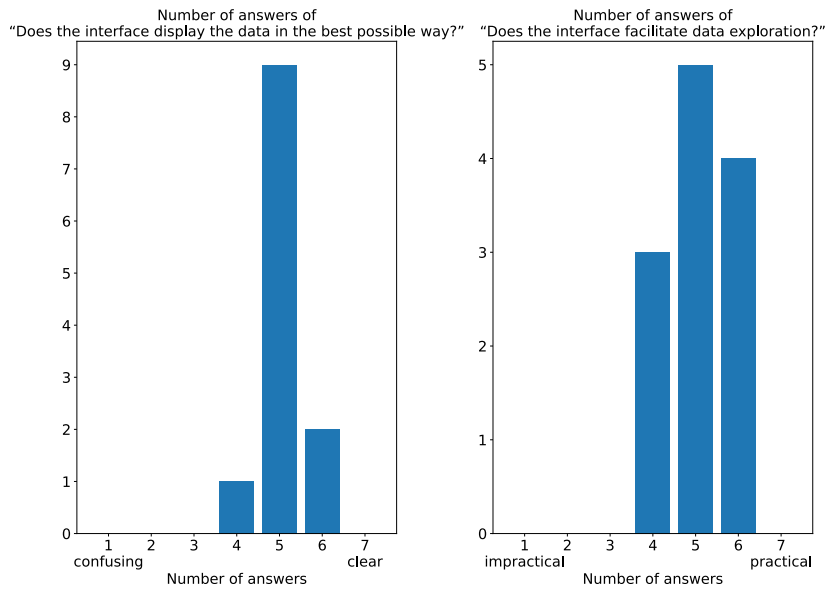


Figure 6.15: Plot of results for questions 3 and 4 about Artwork Data Visualisation User Interface

a datatable. Concerning the quality of the search, they are quite happy with the results found based on their keywords entered and the type of keywords specified.

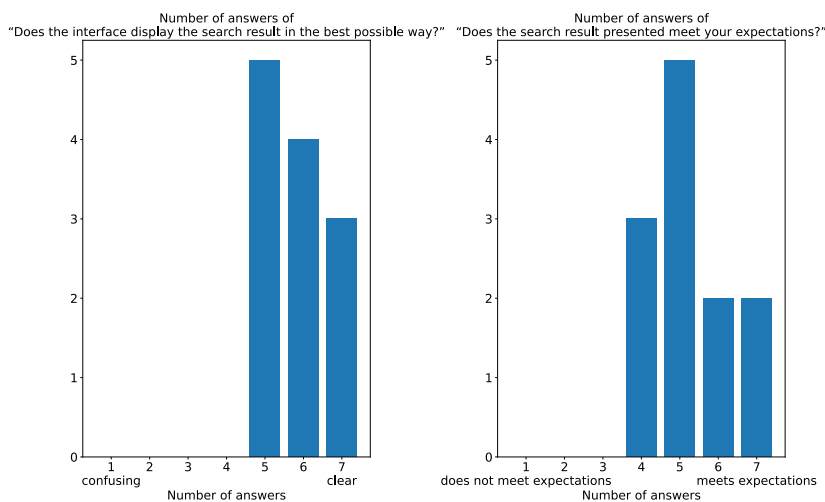


Figure 6.16: Plot of results for questions 3 and 4 about Custom Search User Interface

6.2.6 Requests History User Interface Evaluation Results

As the other interfaces with the same question about the display, we can also say that the people found our user interface pleasant and the data are displayed in the best way. **Figure 6.17** shows the result for the question about the presentation of the request history.

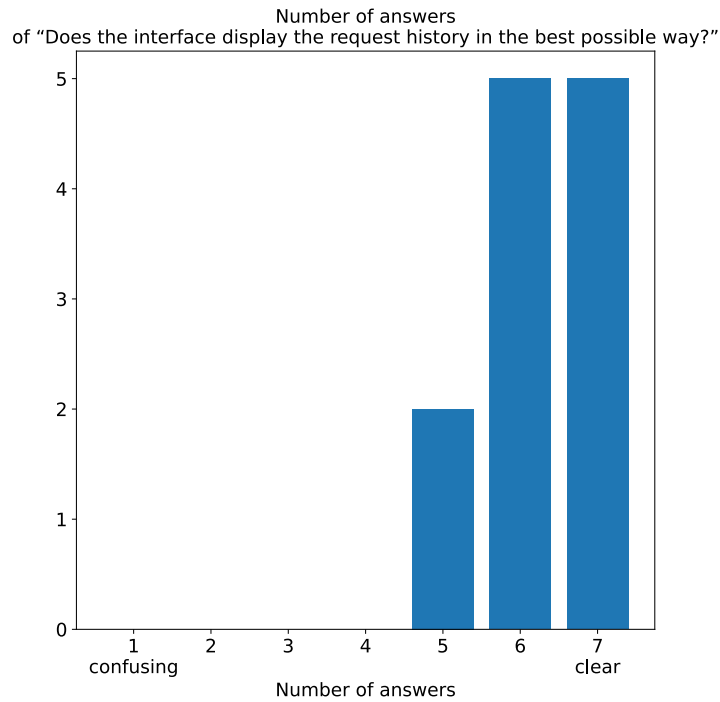


Figure 6.17: Plot of results for question 3 about Requests History User Interface

6.2.7 Artwork and Artist Information Evaluation Results

In our user evaluation, we also interviewed the participants to find out whether the overall data presented to a visitor meet their expectations, as well as individual data for the artworks and for the artists. We asked if they found the data were used properly. **Figures 6.18** and **6.19** show the result of the two questions mentioned above. Regarding whether the data meet user expectations, we can see from the three graphs below that users found

that it met their expectations about overall data as well as individual data used. In terms of the data exploitation, they were able to express that the data were well exploited from their perspective.

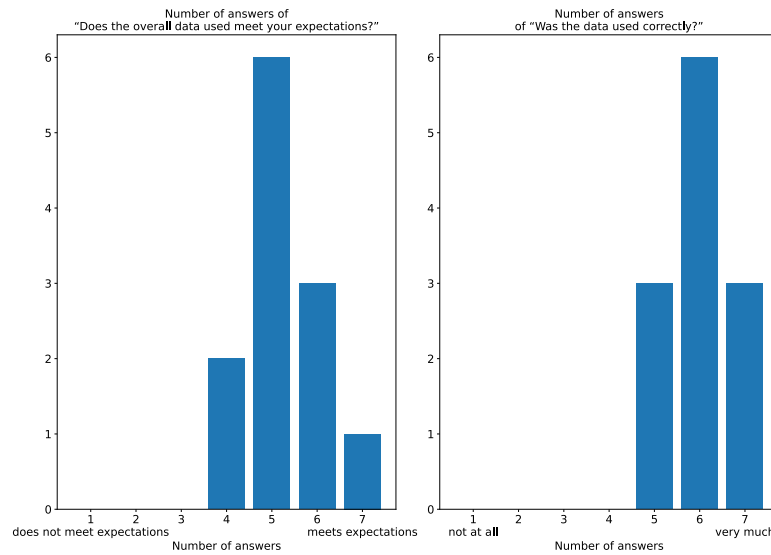


Figure 6.18: Plot of results for questions 1 and 2 about Artwork and Artist Information

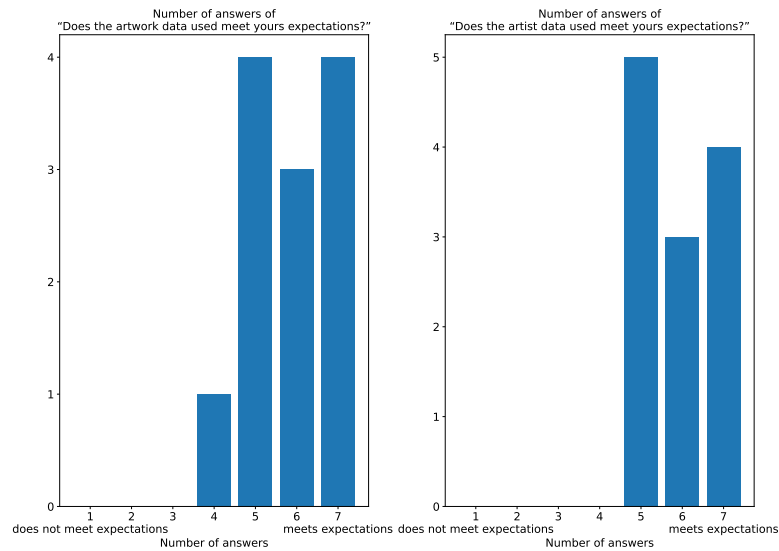


Figure 6.19: Plot of results for questions 3 and 4 about Artwork and Artist Information

6.2.8 Evaluation Conclusion

In conclusion, the user evaluation has identified some improvements based on the recommendations left by the users. Moreover, with the questions about our user interfaces, we could also see that our application and the interfaces are well appreciated by the testers. To summarise, these are the different improvements that we noticed:

- Create tutorial pages.
- Increase the number of markers to have better stability about the augmented reality content.
- Find a way to avoid the picture distortion used in the augmented reality interface, we found that we can avoid that by using the width-height ratio to scale the picture.

7

Future Work and Conclusion

7.1 Conclusion

Through this thesis, we were able to apply what we have learned throughout our studies at the Vrije Universiteit Brussel. In addition, we were able to learn about how best to conduct user research, survey, evaluation, and how to write a thesis.

We would also like to point out that the development of some phases of this brief has been impacted by the health crisis and the containment due to COVID-19 virus. Without this health crisis, the evaluation phase of our application would have been different.

In this thesis, we described our Augmented Reality Museum Guide application. It is an application using augmented reality and the DBpedia semantic database to provide an application that allows easier access to other information about an artwork. The main contributions of our application were:

- Web-based application
- AR interface to display basic and advanced information
- A 2D “Tree View” to visualise and explore the artwork information

The last contributions were not exactly stated like that in **Chapter 1**, but in the development of our solution, we refine it from an AR user interface to a 2D “Tree View”. Our research questions were:

1. How to provide more flexible and advanced information?
2. How can we make the exploration of artwork information attractive and easy to interpret via augmented reality?

To achieve our research questions, we created a web-based application. To give access to a new source of data and a more flexible source. We used SPARQL queries to find information about the scanned artwork from visitors. With the use of a semantic database, this has brought access to the Internet in a field where it has never been used in such a way before. In order to reach our second research questions, we have addressed this in two ways. The first way, it was to use a full augmented reality interface to display basic and advanced information about artwork as shown in **Chapter 6**. The second way, our application allows to explore the “Tree View” of all the data related to an artwork. We did it in 2D regarding the limitations that we encountered during the application development, as stated in **Chapter 5**. We can further use our solution to perform a personalised search to learn more about aspects or other aspects related to art. We were able to show with the related work that there are some applications already using augmented reality in museums. But most of these applications did not use any other information than the basic information made available by the museum curators. Through our applications, we have brought with our contributions a new way of exploring information about an artwork and a new way of experiencing a visit to a museum. In order to make our application useful and interesting, we made a multi-platform application usable via a web browser. For that we thought about the framework used for augmented reality, as well as the basic support of our application. With all this, our application can give rise to a multitude of other additional works.

With the user evaluation of our user application, we were able to understand that overall our application is pleasant to users. They find it useful to have a broader and more flexible access to artwork information. Having conducted this evaluation, we were able to find some improvements, as well as a future improvement.

7.2 Future Work

In our application, we had set out a list of features, and we were able to achieve all of these features with only minor changes to some of these features. The only feature that has been modified due to issues encountered during the development of our application is the customised search (see **Subsection 5.2.3**). As reminder, the issue was the fact that if we made queries too general by not fixing the type of the search, we would get time-outs.

- See basic and advanced artwork information
- See basic and advanced artist information
- See a data visualisation of the data related to an artwork.
- Do customised search
- Consult requests history

With all this, we have been able to list a number of improvements that could improve the quality and interest of our application. In addition, we had time to think about future work that could be done to extend our application.

The first point of improvement we have been able to find is to improve the performance of our queries. The improvement of our queries would allow us to get the results of our queries faster in order to lose the visitors' enthusiasm for the viewed artwork. Another positive aspect of this improvement is to optimise our server to make it more robust.

The second point of improvement that can be applied in our application is the use of the WebXR API framework. Once this technology will be more mature and easily usable, we could use it in our application to replace the current framework. With this point of improvement, we will be able to support more augmented reality into our user interfaces than what we currently have.

Another improvement is the quality of our queries by integrating another source of semantic knowledge, to complete a potential lack of information and to improve the quality of the information that a visitor can consult. While discussing of information quality, we could also integrate artificial intelligence to predict what a visitor would request as information after consulting other information. Artificial intelligence with machine learning algorithms

can also help us in customised search to give visitors the possibility to not fix the type of the search and to find better results to their searches. The positive aspect of this improvement is to offer on one hand more information to visitors and on the other hand to allow a better quality of information.

Finally, the last improvement that could be useful to our application is the standardisation of the structures of all DBpedia versions, i.e. on the properties used to link information, between resources and to standardise the data. As reported in **Chapter 5**, this was a concern we had encountered on different resources between the English and French versions of DBpedia. Therefore, the implementation of a standardisation would help us to reduce the complexity of some of our requests. Thus, de facto, we would be able to improve the speed performance of our requests, as we mentioned in our first point of improvement.

The first addition we can consider extending our application, it is more social interaction. To bring more social interaction, we could do it with the possibility of leaving questions, comments. Also, we can improve it with the possibility of leaving bookmarks, and to share artworks with others. The positive aspect of this extension is to increase user interaction during visits. Thus, it will increase the number of connections to our application when visits were ended to retrieve bookmarks or see all the requests already done.

The second functionality envisaged to make our application more attractive and useful when visiting a museum. The functionality would be a navigation system using augmented reality. The navigation system could be used in different ways. These aspects could be museum tours on different themes such as the century or the style. It could also be useful for visitors to go to artworks that they would have searched using our personalised search or directly selected from the information made available to visitors of a scanned artwork marker. This guidance system would be useful, as it is sometimes very difficult to know where a specific artwork is located. For example, we could use a holographic guide to assist visitors.

Our application can also be used in another way. It may also be useful for our application to be usable in the historic city centre where a major artist lived in the city such as Barcelona with Antoni Gaudí. This other use could be combined perfectly with the navigation in augmented reality.

Finally, we could also extend our application to topics other than art museums. Also, we can think about an audio version for people with visually impaired people. The audio would be triggered based on the visitor's location. The device would be able to respond to voice commands in order to use the different features.



Appendix

A.1 Artworks and Artists Informations Survey

A.1.1 Questionnaire

Artworks and Artists Informations Survey

This questionnaire is designed to gather what basic and advanced information is considered useful concerning artists and their artworks.

The results of this questionnaire will be used as a basis for Alexandre Jacobs's master thesis.

Master's thesis title: An Augmented Reality Museum Guide

Promotor: Prof. Beat Signer

Subject: Use of augmented reality for providing customised supplemental information in museum settings.

*Obligatoire

1. What basic information about an artwork would you like to have in addition to title, artist, year and artwork's description? *

Plusieurs réponses possibles.

- Materials used as support
- Type of painting (e.g. oil painting, ...)
- Whether there are other artworks made by the same artist in the museum
- Art movement
- Some information about the artist (nationality, birthdate and date of death, style)

Autre : _____

2. What advanced information about an artwork would you like to have in addition to the basic one? *

Plusieurs réponses possibles.

- List of artworks from the same century
- List of artworks of the same style
- List of artworks made by the same author
- More pictures of the artwork
- List of interpretations and replicas of the artwork
- Useful links concerning the artwork (scientific articles, press articles, ...)
- Size of the artwork

Autre : _____

3. What basic information about an artist would you like to have in addition to their name, nationality, birthdate and date of death, gender and list of artworks made? *

Plusieurs réponses possibles.

- Art patron (sponsor)
- Disciples (students)
- Art movement/ painting style
- Birth name
- Pictures
- Influencer of and influenced by (list of people)
- Useful links

Autre : _____

Ce contenu n'est ni rédigé, ni cautionné par Google.

Google Forms

A.1.2 Result

Horodateur	What basic information about an artwork would you like to have in addition to title, artist, year and artwork's description?	What advanced information about an artwork would you like to have in addition to the basic one?	What basic information about an artist would you like to have in addition to their name, nationality, birthdate and date of death, gender and list of artworks made?
06/03/2020 20:20:55	Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author	Art movement/ painting style
06/03/2020 20:28:12	Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of artworks made by the same author	Pictures
06/03/2020 20:38:10	Type of painting (e.g. oil painting, ...), Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks from the same century, List of artworks of the same style, List of artworks made by the same author	Art movement/ painting style, Birth name, Pictures, Influencer of and influenced by (list of people), Useful links
06/03/2020 22:30:27	Materials used as support, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	More pictures of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...), Size of the artwork	Art movement/ painting style, Useful links
06/03/2020 23:02:23	Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of interpretations and replicas of the artwork, Remarkable facts about composition, details	Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
07/03/2020 10:38:33	Materials used as support, Type of painting (e.g. oil painting, ...), Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks from the same century, List of artworks of the same style, List of artworks made by the same author, More pictures of the artwork, List of interpretations and replicas of the artwork, Size of the artwork, Information about the context it was painted in : politic, economic, to have an idea of how it influenced the art.	Art patron (sponsor), Disciples (students), Art movement/ painting style, Pictures, Influencer of and influenced by (list of people), Useful links, if he was recognized by it's peers at the time of the painting, and if/ if not : why
07/03/2020 10:54:50	Materials used as support, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of artworks made by the same author, List of interpretations and replicas of the artwork	Pictures
07/03/2020 11:05:51	Materials used as support, Type of painting (e.g. oil painting, ...), Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, Useful links concerning the artwork (scientific articles, press articles, ...)	Art patron (sponsor), Art movement/ painting style, Birth name
07/03/2020 11:34:42	Art movement	List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...)	Pictures
07/03/2020 11:53:10	Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author	Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
07/03/2020 12:01:25	Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of artworks made by the same author	Art patron (sponsor), Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
07/03/2020 13:32:53	Materials used as support, Type of painting (e.g. oil painting, ...), Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks from the same century, List of artworks of the same style, List of artworks made by the same author, More pictures of the artwork, List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...), Size of the artwork	Art patron (sponsor), Disciples (students), Art movement/ painting style, Birth name, Pictures, Influencer of and influenced by (list of people), Useful links
07/03/2020 14:26:54	Type of painting (e.g. oil painting, ...), Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...), Size of the artwork	Art patron (sponsor), Disciples (students), Art movement/ painting style, Influencer of and influenced by (list of people)

Horodateur	What basic information about an artwork would you like to have in addition to title, artist, year and artwork's description?	What advanced information about an artwork would you like to have in addition to the basic one?	What basic information about an artist would you like to have in addition to their name, nationality, birthdate and date of death, gender and list of artworks made?
07/03/2020 15:38:56	Materials used as support, Type of painting (e.g. oil painting, ...). Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks from the same century, List of artworks of the same style, List of artworks made by the same author, List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...), Size of the artwork, Some information about where the artwork was supposed to be exposed (and for really important artworks a reconstitution in virtual reality of this place)	Art patron (sponsor), Disciples (students), Art movement/ painting style, Birth name, Pictures, Influencer of and influenced by (list of people)
07/03/2020 16:33:46	Whether there are other artworks made by the same artist in the museum, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author, List of interpretations and replicas of the artwork	Birth name, Pictures, Influencer of and influenced by (list of people)
07/03/2020 17:58:18	Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author, Useful links concerning the artwork (scientific articles, press articles, ...)	Art patron (sponsor), Art movement/ painting style, Influencer of and influenced by (list of people)
08/03/2020 07:50:45	Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author	Disciples (students), Art movement/ painting style, Birth name, Pictures
18/03/2020 16:01:48	Whether there are other artworks made by the same artist in the museum, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks from the same century, List of interpretations and replicas of the artwork, Size of the artwork	Birth name, Pictures
18/03/2020 16:33:37	Art movement	List of artworks made by the same author, Useful links concerning the artwork (scientific articles, press articles, ...)	Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
21/03/2020 10:04:45	Type of painting (e.g. oil painting, ...), Art movement, Some information about the artist (nationality, birthdate and date of death, style), Explanation about how to possibly interpret the artwork	List of artworks of the same style	Art patron (sponsor), Disciples (students), Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
21/03/2020 10:14:27	Materials used as support, Type of painting (e.g. oil painting, ...), Some information about the artist (nationality, birthdate and date of death, style)	Size of the artwork	Art movement/ painting style, Birth name, Pictures, Influencer of and influenced by (list of people)
21/03/2020 10:39:26	Type of painting (e.g. oil painting, ...), Whether there are other artworks made by the same artist in the museum, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author, List of interpretations and replicas of the artwork	Influencer of and influenced by (list of people)
21/03/2020 10:44:32	Type of painting (e.g. oil painting, ...), Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks from the same century, List of artworks of the same style, List of artworks made by the same author, Useful links concerning the artwork (scientific articles, press articles, ...)	Disciples (students), Influencer of and influenced by (list of people), Useful links
21/03/2020 13:08:00	Art movement, Some information about the artist (nationality, birthdate and date of death, style)	Useful links concerning the artwork (scientific articles, press articles, ...)	Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
21/03/2020 15:39:25	Type of painting (e.g. oil painting, ...), Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author, List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...)	Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
21/03/2020 20:45:24	Some information about the artist (nationality, birthdate and date of death, style), History of the painting	None during visit	Art movement/ painting style
22/03/2020 02:33:55	Materials used as support, Type of painting (e.g. oil painting, ...), Some information about the artist (nationality, birthdate and date of death, style), dimensions	List of artworks made by the same author, Useful links concerning the artwork (scientific articles, press articles, ...)	Pictures, Useful links
22/03/2020 10:34:12	Type of painting (e.g. oil painting, ...), Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...)	Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)

Horodateur	What basic information about an artwork would you like to have in addition to title, artist, year and artwork's description?	What advanced information about an artwork would you like to have in addition to the basic one?	What basic information about an artist would you like to have in addition to their name, nationality, birthdate and date of death, gender and list of artworks made?
23/03/2020 11:34:28	Type of painting (e.g. oil painting, ...), Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of artworks made by the same author, List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...)	Disciples (students), Art movement/ painting style, Influencer of and influenced by (list of people)
27/03/2020 13:15:16	Materials used as support, Art movement, Meaning of the artwork	List of artworks of the same style, Useful links concerning the artwork (scientific articles, press articles, ...)	Art movement/ painting style, Influencer of and influenced by (list of people)
31/03/2020 09:16:28	Type of painting (e.g. oil painting, ...), Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author	Disciples (students), Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
02/04/2020 17:43:31	"Augmented Reality" -> 3d views, short clips from documentaries on the making of, the life of, the art period, a 3d time line and links with other work, corresponding music from that time, ... so much more than static info I could also read from a small note next to it	Same remark as the first point. Show how the restauration worked in a small clip, highlight the interesting parts in an overlay,	So all the info you propose could be there but the way you present it is more important than the what. Let the user select what he/she wants to see.
08/04/2020 15:23:48	Materials used as support, Type of painting (e.g. oil painting, ...), Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of artworks made by the same author, List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...)	Art patron (sponsor), Disciples (students), Art movement/ painting style, Birth name, Pictures, Influencer of and influenced by (list of people)
09/04/2020 20:49:10	Whether there are other artworks made by the same artist in the museum, Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks from the same century, List of artworks of the same style, List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...), Size of the artwork	Art patron (sponsor), Disciples (students), Art movement/ painting style, Pictures
11/04/2020 20:21:01	Materials used as support, Type of painting (e.g. oil painting, ...), Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks from the same century, List of artworks of the same style, List of artworks made by the same author, List of interpretations and replicas of the artwork	Art patron (sponsor), Disciples (students), Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
11/04/2020 20:29:00	Art movement, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of artworks made by the same author, More pictures of the artwork	Disciples (students), Art movement/ painting style, Pictures, Influencer of and influenced by (list of people)
11/04/2020 20:37:18	Type of painting (e.g. oil painting, ...), Whether there are other artworks made by the same artist in the museum, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author, More pictures of the artwork, Size of the artwork	Art movement/ painting style, Birth name, Pictures, Influencer of and influenced by (list of people)
11/04/2020 20:40:46	Some information about the artist (nationality, birthdate and date of death, style)	List of artworks made by the same author, More pictures of the artwork, Size of the artwork	Pictures, Influencer of and influenced by (list of people)
11/04/2020 21:53:12	Whether there are other artworks made by the same artist in the museum, Some information about the artist (nationality, birthdate and date of death, style)	List of artworks of the same style, List of artworks made by the same author	Disciples (students), Influencer of and influenced by (list of people)
12/04/2020 09:22:29	Type of painting (e.g. oil painting, ...)	List of artworks from the same century, List of artworks made by the same author, Useful links concerning the artwork (scientific articles, press articles, ...)	Influencer of and influenced by (list of people), Useful links
12/04/2020 09:23:02	Art movement	List of artworks made by the same author, List of interpretations and replicas of the artwork, Useful links concerning the artwork (scientific articles, press articles, ...)	Pictures, Useful links

2. Do you have some recommandations?

Augmented Reality User Interface

3. Is the interface comfortable? *

Une seule réponse possible.

	1	2	3	4	5	6	7	
terrible	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	wonderful

4. Is the interface easy to use and to understand? *

Une seule réponse possible.

	1	2	3	4	5	6	7	
difficult	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	easy

5. Do you have some recommandations?

Artwork Data Visualisation UI

22. Does the artwork data used meet yours expectations? *

Une seule réponse possible.

	1	2	3	4	5	6	7	
does not meet expectations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	meets expectations

23. Does the artist data used meet yours expectations? *

Une seule réponse possible.

	1	2	3	4	5	6	7	
does not meet expectations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	meets expectations

24. Do you have some recommandations?

Ce contenu n'est ni rédigé, ni cautionné par Google.

Google Forms

A.2.2 Result

Horodateur	Overall reaction to the application [1 = Obstructive, 7 = Supportive]	Overall reaction to the application [1 = Complicated, 7 = Easy]	Overall reaction to the application [1 = Inefficient, 7 = Efficient]	Overall reaction to the application [1 = Confusing, 7 = Clear]	Overall reaction to the application [1 = Boring, 7 = Exciting]
23/05/2020 21:07:42	6	5	5	5	6
23/05/2020 22:02:30	5	4	6	4	6
26/05/2020 21:08:01	4	2	4	2	6
28/05/2020 18:13:47	6	6	5	5	6
28/05/2020 18:17:41	7	7	5	5	6
28/05/2020 18:28:30	6	6	7	6	7
28/05/2020 18:30:09	6	7	5	5	5
28/05/2020 18:31:22	7	7	6	6	6
28/05/2020 19:01:09	3	4	5	5	5
28/05/2020 21:46:04	2	6	3	3	6
01/06/2020 12:38:41	6	5	6	7	4
01/06/2020 12:39:58	5	5	6	5	6

Horodateur	Overall reaction to the application [1 = Not Interesting, 7 = Interesting]	Overall reaction to the application [1 = Conventional, 7 = Inventive]	Overall reaction to the application [1 = Usual, 7 = Leading edge]	Do you have some recommendations?	Is the interface comfortable?	Is the interface easy to use and to understand?
23/05/2020 21:07:42	7	6	6		6	5
				With a smartphone, the buttons move a lot and it's difficult to read or click on them. Maybe the app can be less sensitive to the movement.		
23/05/2020 22:02:30	6	5	6		4	5
				More explanations on the different functionalities, and on how to use them.		
26/05/2020 21:08:01	7	7	6		4	3
28/05/2020 18:13:47	6	6	6		5	5
28/05/2020 18:17:41	5	5	4		4	6
28/05/2020 18:28:30	6	6	6		5	5
28/05/2020 18:30:09	5	5	5		5	5
28/05/2020 18:31:22	5	5	5		6	6
				- I would put the left buttons closer to the artwork - The interface is moving a lot, which makes reading the artwork description difficult maybe fixing it with more reference points would make it more stable - Use higher resolution image for the artwork description		
28/05/2020 19:01:09	6	6	7		3	5
28/05/2020 21:46:04	5	7	6		5	4
01/06/2020 12:38:41	7	6	5		4	4
01/06/2020 12:39:58	5	5	5		5	5

Horodateur	Do you have some recommandations?	Is the interface comfortable?	Is the interface easy to use and to understand?	Does the interface display the data in the best possible way?	Does the interface facilitate data exploration?	Do you have some recommandations?
23/05/2020 21:07:42			6	5	6	6
23/05/2020 22:02:30			4	5	4	6
26/05/2020 21:08:01			5	6	5	5
28/05/2020 18:13:47	Maybe try to have tutorial page on how to use the application.		5	5	6	4
28/05/2020 18:17:41	Try to have other marker to anchor the elements to stabilise the buttons		5	6	5	6
28/05/2020 18:28:30			5	5	5	5
28/05/2020 18:30:09			7	5	5	5
28/05/2020 18:31:22			7	6	5	6
28/05/2020 19:01:09			4	7	5	4
28/05/2020 21:46:04	replace image of text by actual text so it doesn't get blurry and position the buttons closer to the artwork so it is easier to click on them (I couldn't click on some buttons)		5	4	5	4
01/06/2020 12:38:41			4	4	5	5
01/06/2020 12:39:58			5	5	5	5

Horodateur	Is the interface comfortable?	Is the interface easy to use and to understand?	Does the interface display the search result in the best possible way?	Does the search result presented meet your expectations?	Do you have some recommandations?	Is the interface comfortable?
23/05/2020 21:07:42		5	5	6	6	5
23/05/2020 22:02:30		4	5	5	7	4
26/05/2020 21:08:01		6	5	5	5	6
28/05/2020 18:13:47		5	4	5	5	6
28/05/2020 18:17:41		5	7	7	5	7
28/05/2020 18:28:30		6	6	6	5	6
28/05/2020 18:30:09		7	7	7	4	7
28/05/2020 18:31:22		6	6	6	6	5
28/05/2020 19:01:09		5	5	5	Cannot click on the 4 links in the results	6
28/05/2020 21:46:04		7	7	7	7	7
01/06/2020 12:38:41		6	7	5	4	7
01/06/2020 12:39:58		7	6	6	5	6

Horodateur	Is the interface easy to use and to understand?	Does the interface display the request history in the best possible way?	Do you have some recommendations?	Does the overall data used meet your expectations?	Was the data used correctly?
23/05/2020 21:07:42	5	6		6	7
23/05/2020 22:02:30	5	5		7	7
26/05/2020 21:08:01	6	6		6	6
28/05/2020 18:13:47	6	6		5	6
28/05/2020 18:17:41	7	7		5	5
28/05/2020 18:28:30	6	6		4	6
28/05/2020 18:30:09	7	7		5	5
28/05/2020 18:31:22	5	5		5	6
28/05/2020 19:01:09	7	7		4	7
28/05/2020 21:46:04	7	7		6	6
01/06/2020 12:38:41	7	7		5	5
01/06/2020 12:39:58	6	6		5	6

Horodateur	Does the artwork data used meet yours expectations?	Does the artist data used meet yours expectations?	Do you have some recommendations?
23/05/2020 21:07:42	7	7	
23/05/2020 22:02:30	7	7	
26/05/2020 21:08:01	6	6	
28/05/2020 18:13:47	6	6	
28/05/2020 18:17:41	5	5	
28/05/2020 18:28:30	5	5	
28/05/2020 18:30:09	5	5	
28/05/2020 18:31:22	6	6	
28/05/2020 19:01:09	7	7	
28/05/2020 21:46:04	7	7	
01/06/2020 12:38:41	4	5	
01/06/2020 12:39:58	5	5	

A.3 Step-By-Step Installation Guide

This step-by-step installation guide is done in such way that after one completes all the following steps. One will be able to be run our server locally on a computer running under a Linux distribution as operating system. The full code of our application can be found at https://gitlab.com/AlexJacobs95/master_thesis_app_alexjaco. To run our application, one will need the following requirements:

- Python 3.8
- Flask
- PostgreSQL 12
- Pillow
- SPARQLWrapper

The first step consist of configuring your terminal with environments variables, after downloading the code from the Gitlab repository. To do that, we will use `autoenv`, it helps to execute a list of commands every time we access a specific directory from a terminal. In order to that, one just need to excute the following commands-line in a terminal at the root application code directory: `echo "source 'which activate.sh'" >> ~/.bashrc` and `source ~/.bashrc`.

The second step, it is to check if all python package requirements are already installed. For that open a terminal where the application code is stored, and then one have to run the following command-line `pip install -r requirements.txt`.

The last step of our application is to install the latest version of PostgreSQL. Once it is done, one just need to create the database. To do that, one need to run this command-line in a terminal `psql` which open a PostgreSQL console, then types `create database thesis_alexjaco_app`. Once completed, one will need to create the structure of our database by doing those command-lines `python manage.py db init`, `python manage.py db migrate`, and `python manage.py db upgrade`. After that, one will need to fill our database with predefined content by doing this `python database_filler.py`.

After all those steps, one can run this command-line `python app.py`. This starts our application server, and makes available our web-based application at a localhost address.

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