1. DOCUMENT STRUCTURE

1.1 PROBLEM DOMAIN

1.2 PROPOSED SYSTEM

In this section, the main aspects of the application will be described, such as:

- Functional requirements: definition of the functions of the system.
- Non-functional requirements: specific constraints, not directly related to system functionality, such as usability or performance restrictions.
- Scenarios: fictitious stories of a user's experience with the system.
- Use case model: a model depicting the interaction between the actors and the application;
- Interface mock-ups: an early sketched prototype of the user interface.

1.3 DEFINITIONS AND ACRONYMS

AI: Artificial Intelligence;
AR: Aumented Reality;
TTS: Text-To-Speech;
UC: Use Case;
UML: Unified Modeling Language;

2. PROBLEM DOMAIN

When visiting a museum or an art gallery, inspecting a painting is limited to a quick visual analysis and, in some cases, to a small description found on a plate next to it; for the most part, the history behind it and some details get lost and forgotten.

A guide can help with expanding this knowledge, however guided tours are often not included in the ticket price and they … long routes, or are not available at all, like in small private galleries. Any language barrier doesn't make it easier.

Besides, often visiting a museum is not an option for art enthusiasts or young people and online information is frequently scattered and incomplete.

3. PROPOSED SYSTEM

3.1 OVERVIEW

Today's technology easily allows us to perform a deeper interaction with the reality around us, in ways we never imagined before. This interaction can be extended to the artistic world …

The application aims to deliver an enhanced educational experience through the usage of Augmented Reality and Artificial Intelligence technology, in order to provide the user with additional information about a painting or help visually impaired people receive auditive aid. Anyone with a supported device can come across new ways to appreciate art and even discover new details in an evocative piece.

After launching the application, a user will have the ability to scan a painting by using their smartphone's integrated camera; if the image is recognized, the system will then lookup its associated information and generate a virtual head, modelled after the author of the painting using AR. The guide will begin interacting with the user via Text-To-Speech, by narrating the details of the painting and highlighting them on the canvas copy, when possible.

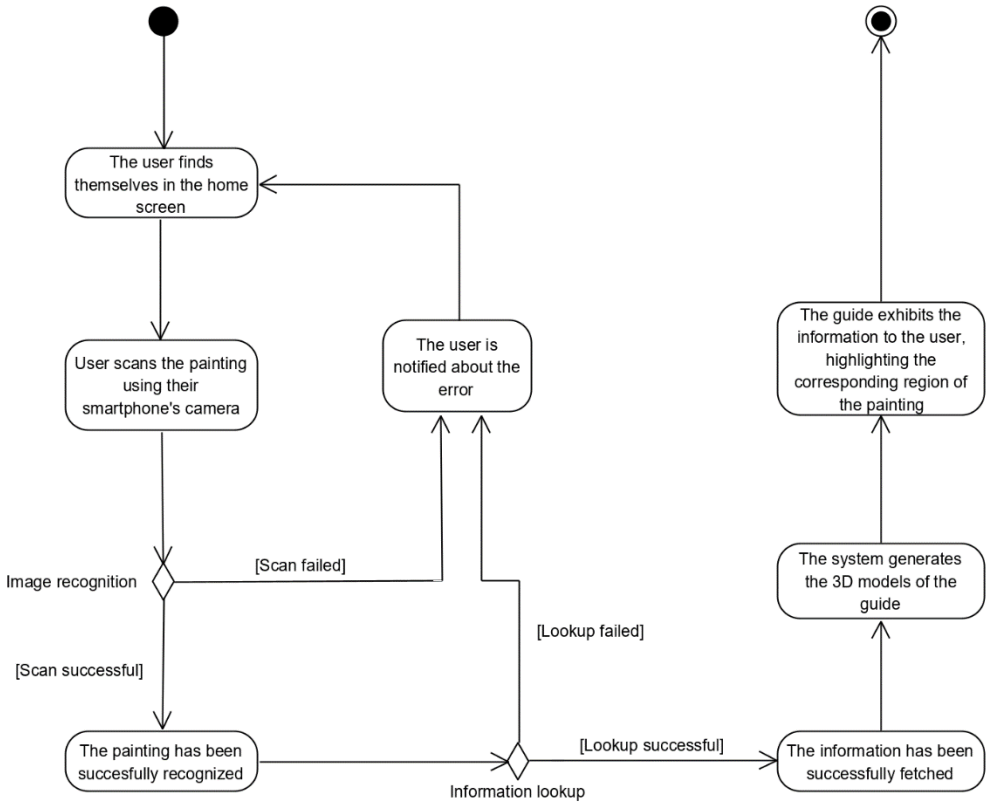


Figure 1 UML activity diagram depicting the interaction between a user and the system.

3.2 VIRTUAL GUIDE AND HIGHLIGHTS

After recognizing a painting, the system will generate a virtual guide, a 3D model of the artist's head and it will communicate with user using TTS.

3.3 GOALS OF THE SYSTEM

The system aims to achieve the following goals:

- Enhance the educational experience for students and art enthusiasts.
- Create an alternative to traditional museum guides.
- Aid visually impaired people experience art.

3.4 FUNCTIONAL REQUIREMENTS

- **FR_1**: The system must allow the user to scan a painting, identifying it via image recognition.
- **FR_2**: The system must be able to retrieve the information associated to a scanned painting.
- **FR_3**: The system must be able to project an augmented reality guide.
- **FR_4**: The system must be able to highlight the details on the painting by using augmented reality.
- **FR_5**: The system must utilize TTS technology when providing the user with the requested information.
- **FR_6**: The system must provide the possibility to use subtitles for the guide's voice.
- **FR_7**: The system must allow an administrator to add a new painting and its related information to the archive.

3.5 NON-FUNCTIONAL REQUIREMENTS

3.5.1 USABILITY

- **NFR_U1**: The system's interface must be easy to use and not ambiguous.
- **NFR_U2**: The system must ensure operations are performed in the most direct way available.
- **NFR_U3**: The system must include a user manual.

3.5.2 RELIABILITY

- **NFR_R1**: The information provided by the system must always be reliable and consistent.
- **NFR_R2**: The system must ensure any error message is delivered to the user in less than 3 seconds.

3.5.3 PERFORMANCE

- **NFR_P1**: System response time must not exceed 300ms when performing lookup operations.
- **NFR_P2**: Errors related to … must not exceed the threshold of x occurrences per month.

3.5.4 *SUPPORTABILITY*

- **NFR_S1**: The system must include an exhaustive documentation, in order to more easily support maintenance.

3.6 *SCENARIOS*

Scenario name	MuseumUsage
Scenario ID	SC_1
Participants	Ann: art student visiting the Salvador Dalí Museum in Figueres with her class.
Flow of events	1. Ann is wandering into the halls of the museum when a particular piece catches her eye, Palladio's Corridor of Thalia, so she gets closer and starts examinating it. 2. The girl isn't satisfied with the little information provided by the plate next to the painting and wants to know more. 3. Ellie, one of Ann's classmates suggests her …, to quench her thirst for more details. 4. Ann decides to give it a try, so she downloads the app and, after reading the manual, tries to scan the painting using her smartphone. 5. The system recognizes the painting and proceeds to generate an interactive talking head of the artist, in the space in front of Ann, using AR. 6. The artist then begins to narrate the story of the painting to Ann, in particular he tells Ann how the piece is heavily influenced by Italian Renaissance art. 7. Moving to the painting itself, the guide starts to speak about the strongly lit figure of a girl playing with a skipping rope in the top left, while the corresponding region is highlighted on the canvas.

Scenario name	HomeUsage
Scenario ID	SC_2
Participants	Frank: art enthusiast working from home during quarantine.
Flow of events	1. After being stuck at home for more than three weeks, Frank decides to ... his old photo books. 2. While browsing the pages, the man notices a picture of him next to "The Bedroom" by Vincent Van Gogh, snapped during a trip some years ago. 3. Frank decides to use … to try and get more info on the painting in the picture, so using his phone he scans it. 4. The system correctly recognizes it and proceeds to generate the guide, which begins narrating the details of the painting to Frank.

Scenario name	AidedUsage
Scenario ID	SC_3
Participants	
Flow of events	

3.7 USE CASE MODEL

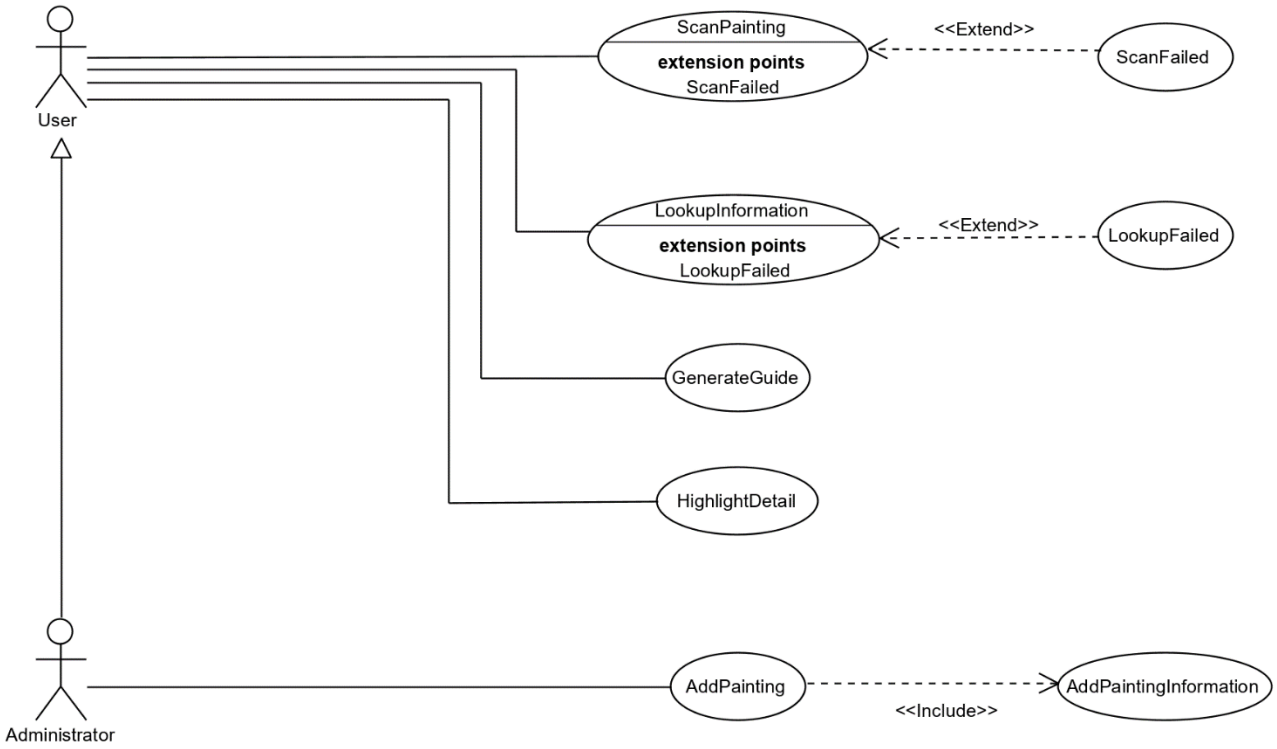


Figure 2 UML Use Case Diagram of the system

Use case name	ScanPainting
Use case ID	UC_1
Participating actors	User
Preconditions	1. The user finds themselves in the home screen
Flow of events	1. The user points the camera towards the painting. 2. The system begins looking for a match of the painting.
Postconditions	The scanning process was successful and the user is waiting for the system to lookup the associated information.
Exceptions	2.1. The system cannot find any match for the painting (Use case "ScanFailed" – UC_1.1).

Use case name	ScanFailed
Use case ID	UC_1.1
Participating actors	User
Preconditions	The system cannot find any match for a painting.
Flow of events	1. The system notifies the user about the error.
Postconditions	The user is redirect in the home screen of the application.

Use case name	LookupInformation
Use case ID	UC_2
Participating actors	User
Preconditions	A painting has been successfully scanned and the user is waiting for the system to lookup the associated information.
Flow of events	1. The system retrieves the painting information in its internal archive.
Postconditions	The system is able to retrieve the requested information.
Exceptions	1.1. The system cannot find any information for the matched painting (Use case "LookupFailed" – UC_2.1).

Use case name	LookupFailed
Use case ID	UC_2.1
Participating actors	User
Preconditions	The system cannot find the information associated to a scanned painting.
Flow of events	1. The system notifies the user about the error.
Postconditions	The user is redirect in the home screen of the application.

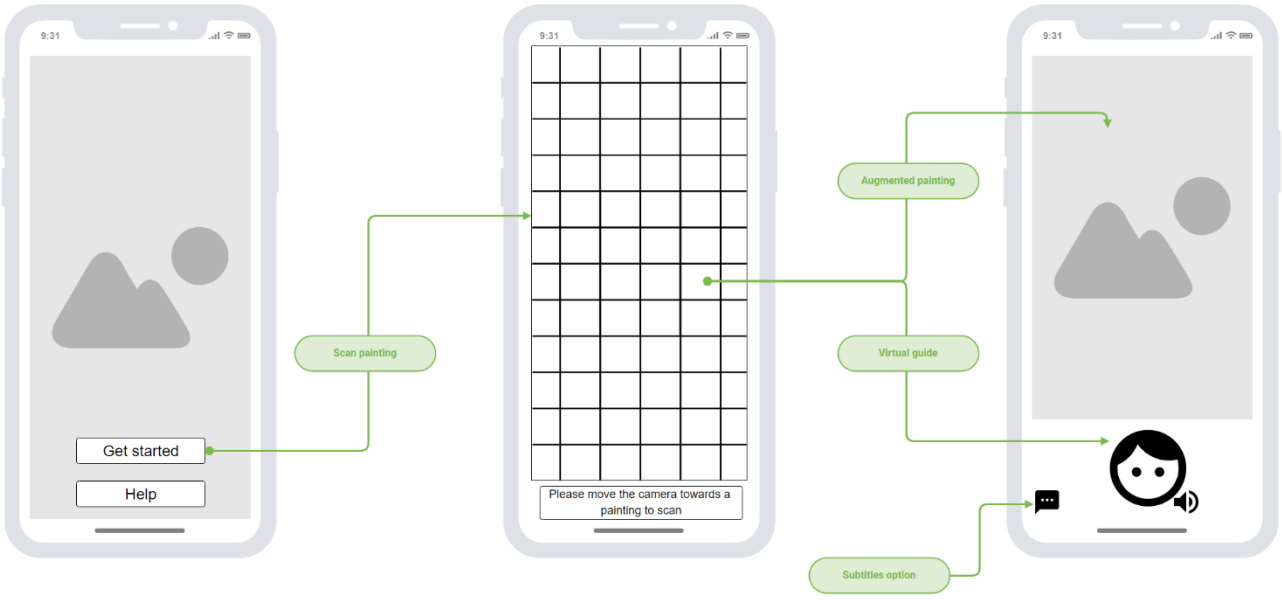
Use case name	GenerateGuide
Use case ID	UC_3
Participating actors	User
Preconditions	User has scanned a painting and the system has correctly recognized it and has retrieved its associated information.
Flow of events	1. Based on the scanned painting's author, the system retrieves the 3D model of the guide to display and projects it in the space pointed by the user.
Postconditions	The 3D guide has been successfully generated in the application.

Use case name	HighlightDetail
Use case ID	UC_4
Participating actors	User
Preconditions	The system has generated the virtual guide for a painting.
Flow of events	1. The guide mentions a region of the painting. 2. The system highlights that region.
Postconditions	The virtual copy of the painting has been successfully generated in the application.

Use case name	AddPainting
Use case ID	UC_5
Participating actors	Administrator
Preconditions	The administrator requests the form to add a new painting.
Flow of events	1. The admininistrator compiles the form with the painting image and the information associated to the it (Use Case "AddPaintingInformation" – UC_6)
Postconditions	The new painting has benn successfully added to the archive and will now be recognized when scanned.

Use case name	AddPaintingInformation
Use case ID	UC_6
Participating actors	Administrator
Preconditions	An administrator is adding a new painting to the archive
Flow of events	
Postconditions	The

3.8 USER INTERFACE MOCK-UPS



4. *SYSTEM ARCHITECTURE*

The system is based on the Model-View-Controller (MVC) architectural pattern, where the functionalities are distributed into three components:
The Model is the central component of the patter; it handles the data, logic and rules of the application, while being independent from the user interface. The View .Finally, the Controller component handles the

Front-end:
and have been an easy choice for us.

Ionic is an open-source SDK that allows the creation of Cross-Platform applications developed using Web technologies like CSS3 and HTML5. It supports a wide variety of front-end frameworks, such as Angular, React or Vue. By using a series of custom web components (custom HTML tags), Ionic provides an easy way to quickly customized the view of the application.
Mobile apps can be built
It allows the user to chose a

Angular is a front-end web development framework …

Apache Cordova is an open-source mobile development framework…. Cordova applications are executed within wrappers targeted to each platform, and rely on standards-compliant API bindings to access each device's capabilities such as sensors, data, network status, etc.
The Cordova plugins we used are:
- Camera:
- Screen orientation
- File:

These three tools greatly complement each-other

Back-end:
On the back-end side, a Node server … for image-processing request. Here an Artificial intelligence component will process the uploaded image using a trained neural network.
Using OpenCV's Node implementation (opencv4nodejs)

5. CASE STUDY

5.1 PAINTING ANALYSIS

As the case study for the development of the application we choose to focus on a

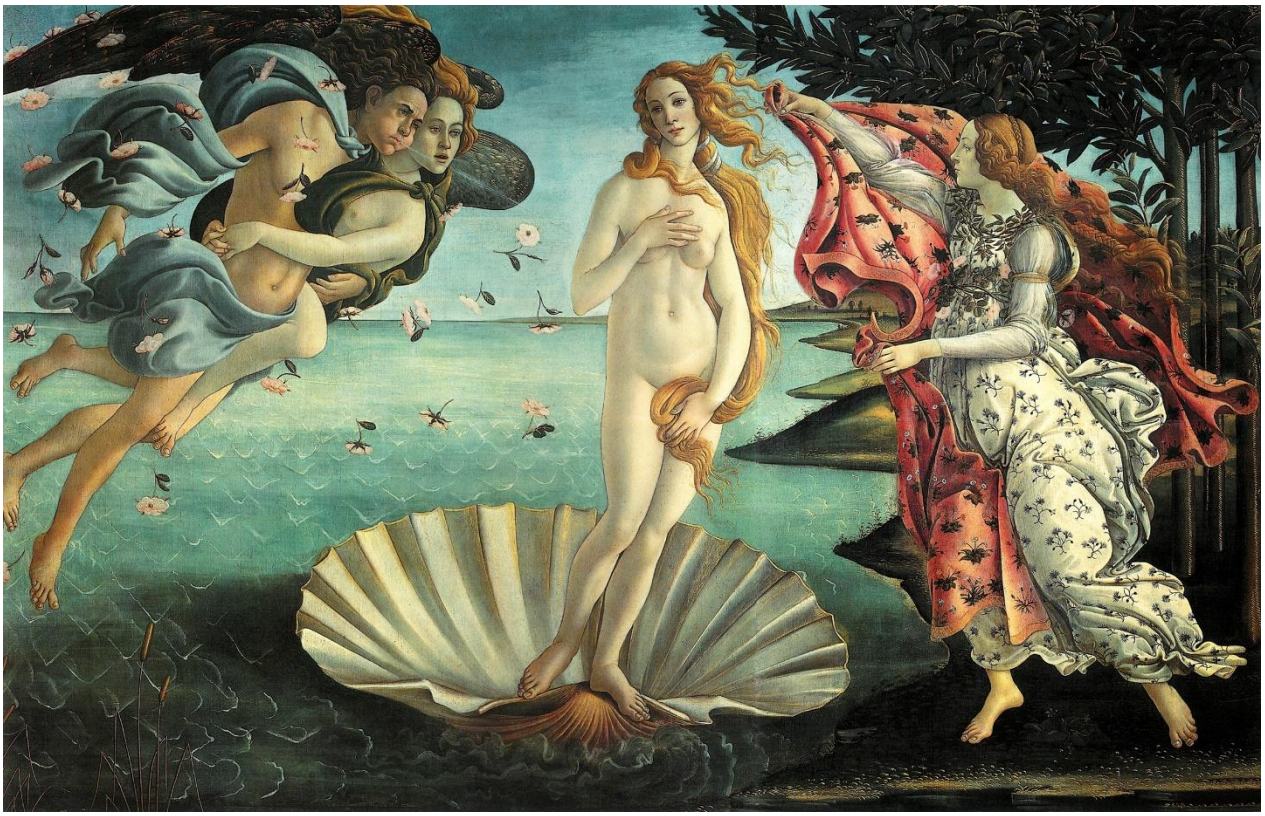


Figure 3 The birth of Venus - Sandro Botticelli

The main focus of the composition is the goddess of love and beauty, Venus, born by the sea spray and blown on the island of Cyprus by the winds, Zephyr and, perhaps, Aura. She is met by a young woman, sometimes identified as the Hora of Spring, who holds a cloak covered in flowers, ready to cover her. A detail often overlooked is the lack of shadows in the scene; according to some interpretations, the … is set in an alternative reality, still very similar to our own.

The goddess is standing on a giant scallop shell, as pure and perfect as a pearl. She covers her nakedness with long, blond hair, which has reflections of light from the fact it has been gilded. The fine modelling and white flesh colour gives her the appearance of a statue, an impression fortified by her stance, which is very similar to the Venus Pudica, an ancient statue of the greek-roman period.

You may wonder why Venus is standing on a shell; the story goes that the God Uranus had a son named Chronus, who overthrew his father and threw his genitals into the sea; this caused the water to be fertilised, and thus the goddess was born.

In the top left of the piece we can notice Zephyrus, god of the winds; he is holding Aura, personification of a light breeze. The two are highlighting the pale face of the goddess, while blowing the shell towards the coast.
Regarding Aura, some scholars are in doubt about her identity; she may in fact be Chloris a nymph which married Zephyrus in an alternative story.

The Hora herself may be a complementary version of the nymph Chloris. Are they two versions of the same person then? It might be; the story of this woman is narrated in “I Fasti” by latin author Ovidio and the painted in “The Spring”, by Botticelli himself, where the woman gets kidnapped by Zephyrus to become a mystical figure. The theory is quite farfetched, however there’s a detail in its favour: the roses falling around her and Zephyrus.

(cfr. D. Mastromattei, La nascita di Venere di Sandro Botticelli: la filosofia che ha cambiato il mondo del ‘500, https://www.arteworld.it/la-nascita-di-venere-sandro-botticelli/)