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Design Project Booklet

InChiesa

Enhancing Religious Tourism through Augmented Reality in Rome's Hidden Churches

“Non Abbiamo Età,
abbiamo già vinto”

Luca Imprudente

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0. INTRODUCTION

Abstract

0 INTRODUCTION

UNWTO Tourism Highlights: 2018 Edition. (2018)

Norberg-Schulz, C. (1979). Genius Loci: Towards a Phenomenology of Architecture

Religious tourism is a constantly growing and fundamental component of cultural tourism worldwide. It attracts over 300 million visitors every year, who travel to visit sacred places that combine spiritual values, cultural identities, and artistic heritage (UNWTO, 2018). This type of tourism is characterized not only by its connection to faith and personal devotion but also by an interest in the so called “Genius Loci”, the atmosphere, identity and symbolism that every sacred place embodies (Norberg-Schulz, 1979). Thus, visiting churches or places of worship is a complex experience in which the religious dimension is tied with the aesthetic, architectural historical and cultural appreciation of works of art and architecture.

The city of Rome is one of the global, leading centers of religious tourism, thanks to its ancient history that combine centuries of artistic production with a long tradition of spiritual centrality. In addition to their devotional role, many of the city's religious buildings house works of art created by prominent figures in Western art history, offering visitors an experience that merge spiritual contemplation, artistic interest, and historical and cultural insight.

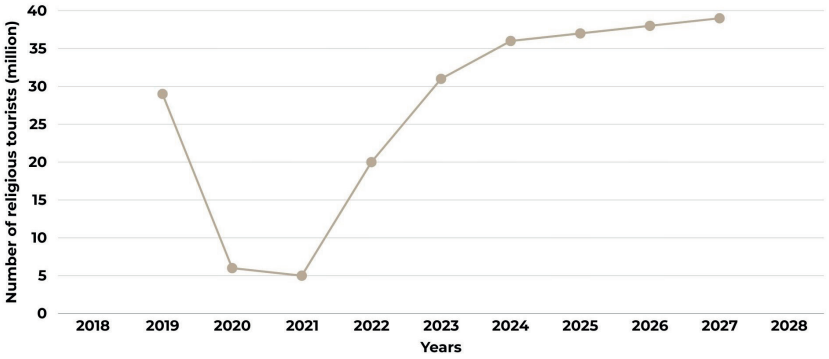


Figure 1 - Graph showing the growing number of tourists

Despite this extraordinary artistic heritage, a significant part of Rome's churches and basilicas, especially those less frequented by the main tourist flows, is at the center of an evident contradiction. Despite presenting works of prestigious historical and artistic value, significant critical issues arise regarding access to information and the valorization of cultural content. In many of these buildings, several factors coexist that limit the full enjoyment of the artistic and spiritual heritage. First, the absence of structured explanatory systems and the lack of multilingual resources reduce the possibilities of understanding the historical, creative, and symbolic meaning of the art pieces. Then, the architectural characteristics of the buildings themselves often hinder direct observation, as numerous frescoes and decorations are located at high points or are distant from the standard line of vision of visitors. Moreover, deterioration phenomena due to the passing of time have, in some cases, compromised significant parts of the works, reducing the perception of the original appearance. Therefore, overall, these conditions compromise the quality and completeness of the church visit experience.

Figure 2 - Complexity of the Sistine Chapel

Beyond this, the research focuses on exploring the applicative potential of Augmented Reality (AR) as an innovative tool to enhance the observation of sacred heritage in less frequented churches of Rome. Hence, the purpose is to evaluate how AR can integrate and enrich traditional models of cultural mediation, overcoming current informational, perceptive, and physical barriers. This process involves the use of digital overlays of contextual information, visual reconstructions, and multimedia narratives. Finally, the research examines the ethical implications of introducing AR technologies into sacred spaces, analyzing how such tools can be designed to comply with the liturgical function and spirituality of places of worship.

Figure 3 - Augmented reality application in Church

To summarize, this project is part of a study that examines the role of digital technologies in enriching cultural and religious heritage, with a specific focus on the use of immersive solutions in sacred contexts. Therefore, the research makes an original contribution to the design field, addressing a theme that is still evolving: the use of AR not only as a tool for technological innovation but also as a design resource for the evolution of cultural mediation models, respecting the identity and spiritual function of places.

01. PRIMARY RESEARCH

Desk research

1.1 Religious heritage and traditional models of cultural mediation

In the global cultural landscape, religious heritage represents an increasingly relevant and strategic component. Approximately 20% of the recognized United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage sites have a spiritual or religious connection, making it the largest thematic category within the list. From an economic point of view, according to estimates by Grand View Research (2024), the global religious tourism market was valued at 254.3 billion dollars in 2023. Furthermore, the growth forecast for 2030 is expected to reach 671.9 billion, with a Compound Annual Growth Rate (CAGR) of 15.3% (Grand View Research, 2024). These data demonstrate not only the increasing attractiveness of religious tourism but also its leading, global role in driving cultural, social, and economic development.

UNESCO World Heritage Centre. (2023). World Heritage and religious heritage.

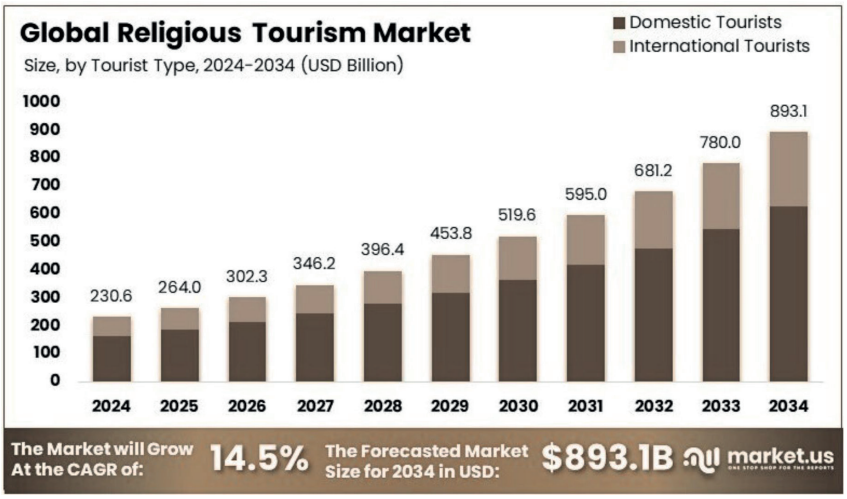


Figure 3 - Economic growth statistics

In addition to this quantitative relevance, religious heritage plays a key role in the conservation and transmission of artistic elements of colossal importance. Churches, basilicas, and places of worship preserve works of art that have accumulated over the centuries, such as, frescoes, sculptures, stained glass windows, and decorative elements, which document the stylistic and iconographic evolution of entire historical eras. However, what gives religious heritage its uniqueness does not reside solely in the mere physical dimension or artistic component but in its ability to embody spiritual and symbolic meanings deeply rooted in local contexts. Religious places represent spaces in which collective values and community memories are sedimented, contributing to the generation of the aesthetic and emotional sense of the visit experience (Bowman, 2010). This intertwining of dimensions renders religious heritage a complex and multidimensional reality, capable of simultaneously involving both material and immaterial elements, as well as individual and collective aspects.

Grand View Research. (2024). Religious tourism market size, share & trends report, 2024–2030.

In order to fully understand the complexity of religious heritage, it is necessary to employ cultural mediation tools that facilitate the appreciation of artistic and spiritual content. This mediation is entrusted to traditional models such as information panels, brochures, guided tours, and audio guides, whose degree of effectiveness varies according to the nature and complexity of the religious sites (McKercher & du Cros, 2020). Although these tools have long represented the basis of cultural mediation in religious sites, they present several critical issues related to the very nature of the content and the growing heterogeneity of the audience. These devices provide a basic level of descriptive information, which is often insufficient to activate complex cognitive processes in visitors, thereby limiting their complete understanding of the symbolic and contextual meanings of religious places (Moscardo, 1996). Consequently, information materials are often standardized, lacking theological contextualization, and poorly adapted to varying levels of public knowledge (Shackley, 2001). This deficit in cultural mediation creates a barrier for the visitor, who is faced with works of art that are difficult to understand independently.

Du Cros, H., & McKercher, B. (2020). Cultural tourism. In Routledge eBooks.

Moscardo, G. (1996). Mindful visitors. Annals of Tourism Research, 23(2), 376–397.

UNESCO World Heritage Centre. (2023). World Heritage and religious heritage.

In addition to these limitations, critical issues emerge related to the spatial characteristics of the sites. The architectural configuration of many sacred spaces can limit complete visual access to the works, as in the case of frescoes placed in elevated positions, thus compromising the perception and the overall experience of the visit (Poria et al., 2003). Moreover, the deterioration phenomena of the works further accentuate these difficulties. Frescoes and wall decorations are particularly vulnerable to degradation processes caused by unstable environmental conditions, which progressively compromise the readability of the works (Mora et al., 1999).

UNESCO World Heritage Centre. (2023). World Heritage and religious heritage.

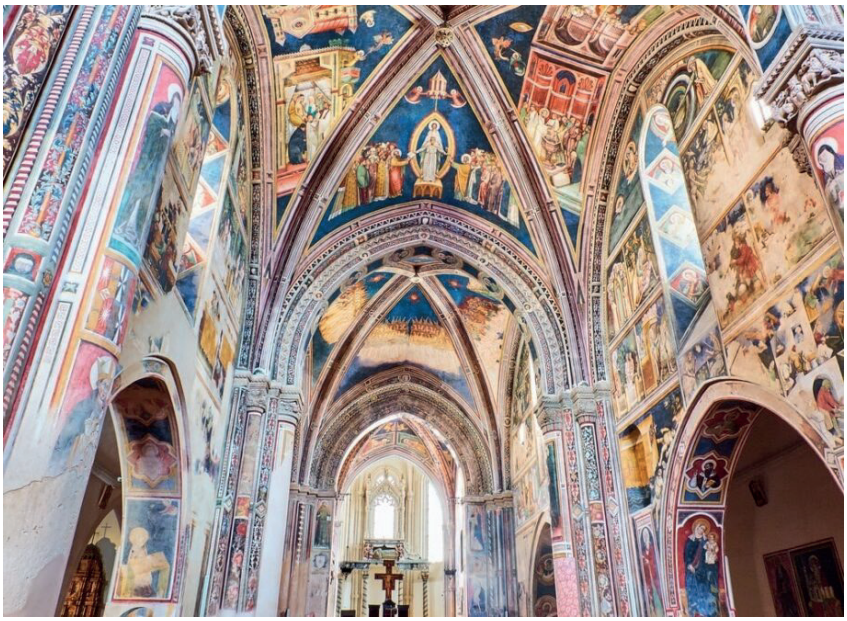


Figure 4 - Ruined frescoes of Galatina

Indeed, the limitations analyzed so far raise the need to rethink the models of cultural mediation applied to these spaces. Especially in contexts characterized by a high concentration of religious sites, as happens in the Italian panorama. Many places that house works of artistic importance are often excluded from the main tourist itineraries and consequently receive limited visibility (Di Giovine, 2009). It is precisely on these premises that the theoretical and design reflections oriented towards the introduction of new interpretative technologies, such as AR, are developed, which will be the subject of analysis in the following paragraphs.

UNESCO World Heritage Centre. (2023). World Heritage and religious heritage.

1.2 Enhancement of Cultural Heritage through Augmented Reality

In recent years, AR has progressively established itself as one of the most relevant emerging technologies in numerous application fields. This tool involves the real-time integration of digital content within the physical environment perceived by the user, resulting in a single, unified perceptual experience in which real and virtual elements coexist and interact (Azuma, 1997). AR is today applied in numerous fields, including industry, healthcare, education, design, and entertainment, as documented in several synthesis contributions on the development of the technology (Billinghurst et al., 2015; Carmigniani et al., 2011). The ability to enrich the information context perceived by users, combining three-dimensional digital content, contextual information, and real-time interaction, has also aroused increasing interest in the field of cultural tourism, in particular for the enhancement and interpretation of complex historical-artistic sites (Yovcheva et al., 2012). In this context, numerous scientific contributions have analyzed the potential of AR in enriching the visit experience and overcoming some of the critical issues present in traditional models of cultural heritage fruition (Han et al., 2018; Wojciechowski & Cellary, 2013). Based on this evidence, the following section examines the potential applications of AR in cultural and tourist contexts.

Azuma, R. T. (1997). A survey of augmented reality. PRESENCE Virtual and Augmented Reality, 6(4), 355–385.

Billinghurst, M., Clark, A., & Lee, G. (2015). A survey of augmented reality. Foundations and Trends® in Human–Computer Interaction, 8(2–3), 73–272.

1.2.1 The role of AR in cultural tourism

The use of AR in cultural tourism contexts is the subject of growing academic interest for its ability to transform the visit experience from passive enjoyment to dynamic and personalized interaction. Survey studies have demonstrated that the integration of contextual digital content in cultural heritage sites enhances immersion, emotional engagement, and visitor satisfaction (Bekele et al., 2018; Boboc et al., 2022). In line with these findings, an application study on the Dublin AR system confirmed that embedding contextualized information during visits significantly increases the perceived quality of the visitor experience (Han et al., 2018). Indeed, in terms of interpretative mediation, AR offers a significant contribution. Thanks to the ability to integrate geolocalized and adaptive contextual content, AR allows visitors to access information directly in situ, combining historical narratives, descriptive data, and digital visualizations of the physical elements observed during the visit (Yovcheva et al., 2012). Therefore, the visit experience shifts from a static and standardized information fruition, characterized by limitations, to an adapting experience according to the visitor's paths and needs (Han et al., 2019). In other words, AR enables personalized and dynamic context-aware interaction, where the tool adapts the content in real time based on the user's position, course, and expressed preferences. Consequently, it offers a more in-depth, flexible, and engaging narrative during the visit (Tom Dieck & Jung, 2018). Moreover, thanks to the possibility of integrating three-dimensional reconstructions, virtual visualizations, and interactive narrations, this innovative technology offers a significant contribution to the cognitive and learning processes of visitors. The use of augmented content promotes a greater understanding and memorization of complex concepts, facilitating the decoding of iconographic elements, the reading of architectural details, and the visual reconstruction of original states that are no longer preserved (Wojciechowski & Cellary, 2013).

Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M. (2010). Augmented reality technologies, systems and applications. Multimedia Tools and Applications, 51(1), 341–377.

Yovcheva, Z., Buhalis, D., & Gatzidis, C. (2012). Overview of smartphone augmented reality applications for tourism. International Conference on Information Technology, 10(2), 63–66.

Boboc, R. G., Băutu, E., Gîrbacia, F., Popovici, N., & Popovici, D. (2022). Augmented reality in cultural heritage: An overview of the last decade of applications. Applied Sciences, 12(19), 9859.

Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. Computers & Education, 68, 570–585.

In addition to practical aspects, the integration of augmented content also stimulates attention, improves understanding, and promotes greater memorization of information acquired during the visit experience (Chung et al., 2015). In detail, the use of AR applications in cultural sites facilitates the sedimentation of knowledge by simultaneously activating visual, auditory, and motor channels; consequently, it increases cognitive involvement and produces a positive attitude toward the visited site (Chung et al., 2015). As a result, this advanced experiential dimension proves particularly effective in contexts characterized by high historical and artistic complexity, such as places of worship, where static textual or visual support alone risks being inadequate.

Chung, N., Han, H., & Joun, Y. (2015). Tourists' intention to visit a destination: The role of augmented reality (AR) application for a heritage site. Computers in Human Behavior, 50, 588–599.

This digital tool not only enhance the cognitive and interpretive experience but also creates a significant contribution to the inclusiveness and accessibility of the tourist experience. AR systems enable people to overcome many of the linguistic barriers that characterize traditional information models. For instance, it presents multilingual content, provides automated translations, and incorporates iconographic visual supports that make the content accessible to audiences with diverse geographical origins and cultural backgrounds (Han et al., 2019). Also, AR enables tourists to dynamically adjust the information levels for visitors based on their individual preferences, age, interests, or prior knowledge, thereby promoting personalized and scalable visit itineraries (Tom Dieck & Jung, 2018). Indeed, this adaptive flexibility effectively responds to the needs of heterogeneous audiences, offering personalized itineraries for various visitor categories, including children and individuals with sensory or cognitive disabilities.

Han, D. D., Weber, J., Bastiaansen, M., Mitas, O., & Lub, X. (2019). Virtual and augmented reality technologies to enhance the visitor experience in cultural tourism. In Progress in IS (pp. 113–128).

To summarize, the adoption of AR solutions in tourist-cultural contexts thus contributes to making the enjoyment of heritage more inclusive and accessible, reducing interpretative inequalities, and expanding the potential audience of cultural sites. The combination of these elements confirms that, nowadays, AR represents one of the most promising solutions for innovating models of enjoyment and valorization of cultural heritage, enriching the experiential, interpretive, and educational dimensions of visitors in tourist-cultural contexts.

Jung, T., Dieck, M. C. T., Lee, H., & Chung, N. (2016). Effects of virtual reality and augmented reality on visitor experiences in museum. In Information and Communication Technologies in Tourism (pp. 621–635).

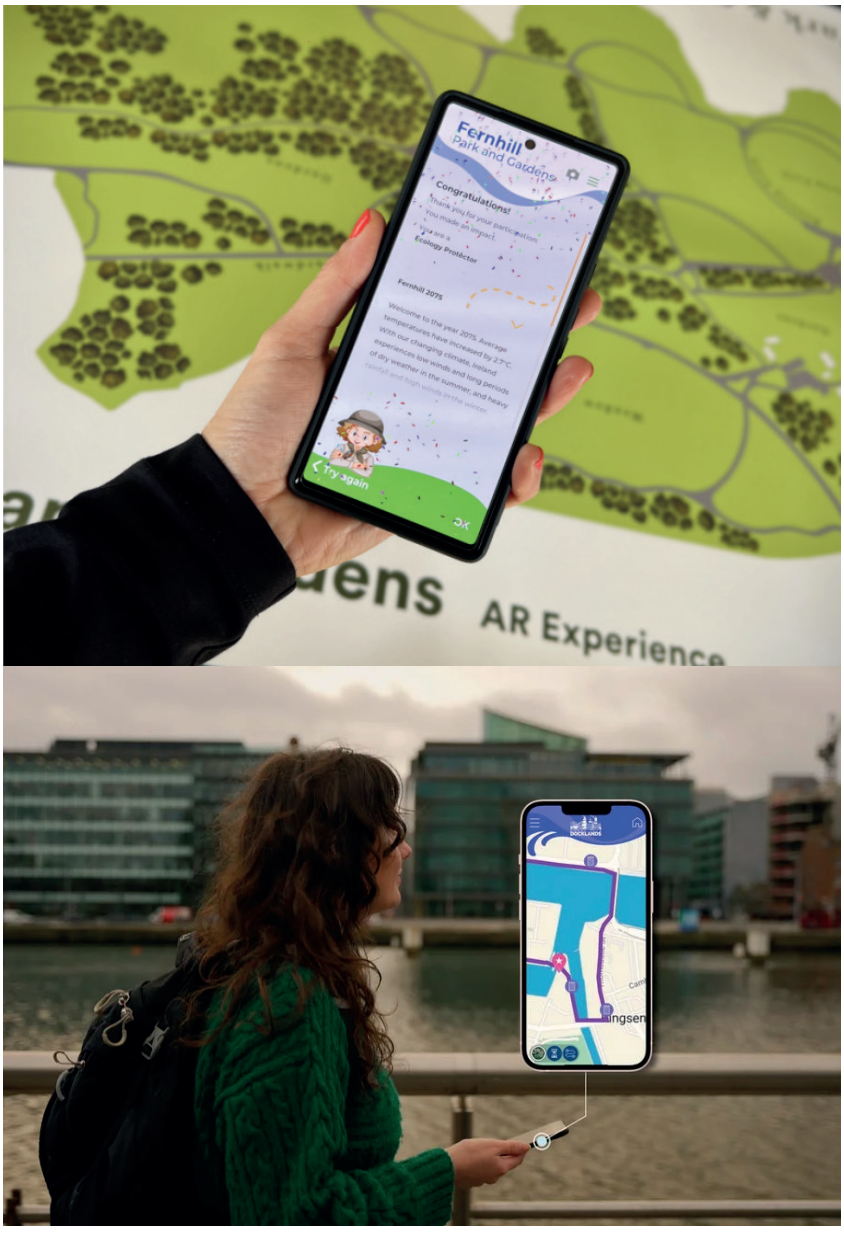


Figure 5 - Dublin City Council has launched a new augmented reality map that allows users to access a virtual map of the city on their mobile device.

1.2.2 Digital preservation and visual reconstruction through AR

In addition to the previously mentioned characteristics, AR is also playing an increasingly important role in the digital preservation of cultural heritage. In many contexts, particularly in places of worship, numerous works of art are now partially damaged, deteriorated, or not fully accessible for direct visual enjoyment due to physical degradation processes, architectural limitations, or conservation constraints (Mora et al., 1985).

Winfield, D., Mora, P., Mora, L., & Philippot, P. (1985). Conservation of wall paintings. Studies in Conservation, 30(4), 191

The integration of AR in the documentation and enhancement processes proposes three-dimensional digital reconstructions and comparative visualizations that reproduce the original states of the works. Thus, it offers visitors the opportunity to perceive iconographic and architectural details that are now compromised or lost (Wojciechowski & Cellary, 2013; Bruno et al., 2010). Indeed, through accurate digital modeling, AR can virtually restore portions of disappeared frescoes, altered chromatic details, or spatial configurations that are no longer accessible. So, besides their informative value for visitors, these applications also provide concrete support for scientific documentation and conservation protection programs. This tool promotes the three-dimensional recording of heritage and its accessibility in a virtual environment for study, training, or preventive monitoring (Forte, 2016; Bekele et al., 2018). Indeed, AR is configured as a design resource for the long-term protection and transmission of material cultural heritage.

Bruno, F., Bruno, S., De Sensi, G., Luchi, M., Mancuso, S., & Muzzupappa, M. (2009). From 3D reconstruction to virtual reality: A complete methodology for digital archaeological exhibition. Journal of Cultural Heritage, 11(1), 42–49.

1.2.3 Experiential enhancement of cultural heritage through AR

The adoption of AR in tourist-cultural contexts is increasingly recognized as a design tool capable of enhancing heritage processes and promoting greater experiential involvement from visitors. Thanks to the possibility of integrating multimedia content into real life, AR transforms the visit into a multisensory experience that stimulates emotions, curiosity, and active participation (Han et al., 2018; Tom Dieck & Jung, 2018). As a result, the visiting experience becomes not only more emotionally engaging but also more effective in terms of learning and understanding the exhibited heritage (Chung et al., 2015; Jung et al., 2015).

Bekele, M. K., Pierdicca, R., Frontoni, E., Malinverni, E. S., & Gain, J. (2018). A survey of augmented, virtual, and mixed reality for cultural heritage. Journal on Computing and Cultural Heritage, 11(2), 1–36.

Han, D., Jung, T., & Gibson, A. (2013). Dublin AR: Implementing augmented reality in tourism. In Information and Communication Technologies in Tourism (pp. 511–523).

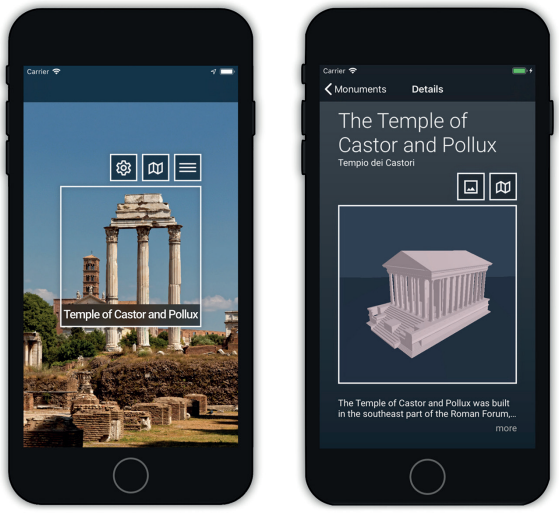


Figure 6 - The Future Urban Legacy Lab Example of augmented reality used in the field of cultural heritage

Forte, M., & Campana, S. (2016). Digital methods and remote sensing in archaeology. In Quantitative methods in the humanities and social sciences.

1.3 AR in sacred spaces and religious contexts

The introduction of immersive technologies in places of worship represents a recent challenge that is still relatively little explored in the international debate on the relationship between digital innovation and religious heritage. Among the most relevant experiments, the Intelligent Cathedrals project (mentioned again later in this research) stated that AR is emerging as one of the most promising experimental tools to enrich the understanding of the artistic and spiritual heritage preserved within sacred spaces, offering new opportunities for cultural mediation and information accessibility (Allal-Cherif, 2022). However, unlike museum or archaeological contexts, the application of digital solutions in sacred places requires particular design attention, as it simultaneously involves artistic, historical, symbolic, and spiritual dimensions. Sacred spaces are not only containers of works of art but living spaces of religious practice, collective identity, and ritual meaning. Consequently, the introduction of technologies such as AR in these contexts raises issues that extend beyond the realm of communicative effectiveness alone. They must also consider the preservation of sacredness, respect for theological meanings, and the risk of interference with the liturgical function (Battista, 2024; Jung, 2023).

Allal-Chérif, O. (2022). Intelligent cathedrals. Technological Forecasting and Social Change, 178, 121604.

Battista, D. (2023). The Digital as Sacred Space: Exploring the online religious dimension. Academicus International Scientific Journal, 29, 21–37.

Jung, D. (2023). Church in the Digital Age: From Online Church to Church-Online. Theology and Science, 21(4), 781–805.

Considering this scenario, a series of still-open reflections emerge, which concern the delicate balance between technological innovation and respect for the symbolic and spiritual functions of sacred spaces. In recent years, several international experimental projects have initiated concrete reflections on the use of AR in religious contexts. They provided valuable insights into how this technology can be integrated into such settings, highlighting both the potential and the critical issues still to be addressed in managing religious and cultural meanings. The following paragraphs will analyze the ethical and cultural issues that AR raises, which extend beyond technological

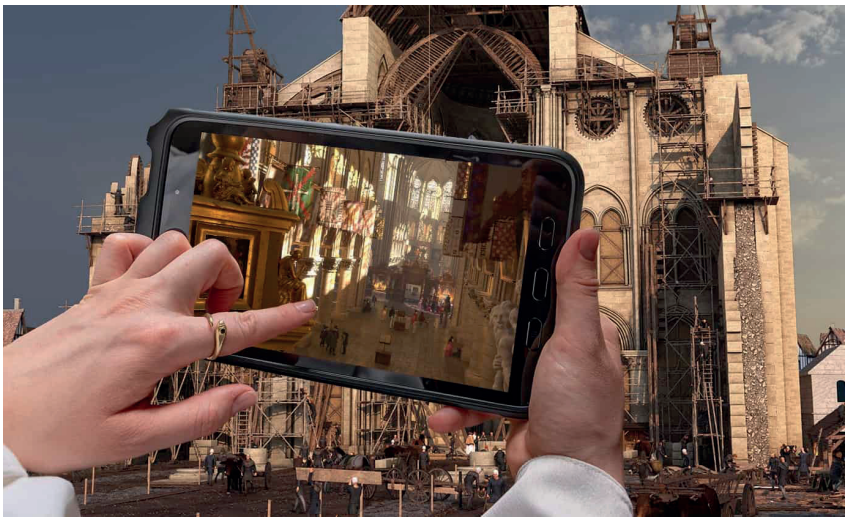


Figure 7 - AR App by Church of Notre Dame, Paris

1.3.1 Ethical and cultural tensions related to the introduction of AR in sacred places

The first issue that emerged in international literature involves the risk of "spectacularization" and trivialization of the sacred experience. The excessive use of interactive elements, visual animations, or digital reconstructions could transform the religious experience into a simple, spectacular tourist event (Battista, 2024; Jung, 2023). So, it would reduce the spiritual depth of the place to a superficial narrative oriented towards entertainment (Battista, 2024; Jung, 2023).

The second issue involves the potential for the commodification of sacredness. It presents the possibility that AR is used primarily as a tool for attracting tourists, thereby bending the religious meaning to the logic of cultural consumption. Such applications risk transforming religious sites into platforms for experiential consumption, generating tensions between the devotional and commercial functions of places of worship (Hassan, 2023).

Rakib, M. U. H. K., & Hassan, A. (2023). Factors prompting augmented reality adoption in sacred places. International Journal of Tourism Policy, 13(3), 187.

Another critical issue concerns the management of the boundary between tourist experience and liturgical function, dimensions that must inevitably coexist in sacred places. Places of worship are, first and foremost, spaces dedicated to religious practice, and only subsequently can they accommodate educational, cultural, or tourist functions. However, different positions coexist within the same religious communities (Laato et al., 2024). On the one hand, some clergy express reservations regarding the excessive use of AR devices during liturgical moments or prayers (Laato et al., 2024). On the other, favorable positions emerge that recognize the potential of AR in facilitating the iconographic and historical understanding of sacred heritage, provided that its use occurs in ways that respect the ritual context (Laato et al., 2024). For example, the project "Intelligent Cathedrals," which focused on overcoming physical limitations by offering profound spiritual experiences, addressed the issue of compatibility between technological innovation and sacredness through flexible design solutions (Allal-Cherif, 2022). In particular, a system was defined to regulate the times and spaces in which AR contents can be activated, clearly distinguishing between moments of tourist use and those dedicated to religious celebrations. It would thus avoid possible interference with devotional practices and maintain the integrity of the rite.

Laato, S., Rauti, S., Laato, A. M., Al-Msallam, S., Jung, S., Sutinen, E., & Hamari, J. (2024). Sacred Spaces in the Digital Age: Perceptions of Lutheran Christian priests on augmented reality at holy Sites. ACM International Conference on Interactive Media Experiences, 9, 256–267.

1.3.2 Designing AR in sacred places: guidelines for respectful and enhancing design

The integration of AR in sacred contexts requires an ethically aware and culturally sensitive design approach that preserves the liturgical function and spiritual meaning of the places without renouncing the potential offered by technology. In this process, the direct involvement of religious authorities and local stakeholders enables the definition of shared design solutions that respect theological sensitivities and ritual specificities (Laato et al., 2024). A conscious co-design allows not only to avoid improper interpretations of sacred contents but also to enhance the potential of AR in supporting the understanding of religious symbolism.

Hence, through multimedia elements such as visual reconstructions or three-dimensional models, this technology can make iconographic elements accessible, which are not always easily decipherable for non-expert visitors. Consequently, digital tools facilitate artistic, historical, and religious insight without altering the devotional function of the place (Wojciechowski & Cellary, 2013). From this perspective, AR can offer respectful support to promote the understanding of liturgical content, even for those who do not belong to the reference confessional tradition, without compromising the devotional dimension of the place (Tom Dieck & Jung, 2018; Han et al., 2019). To ensure that the information provided by AR respects the liturgical context, particular attention must be paid to the way digital content is presented during the experience, avoiding visually intrusive forms.

Based on these principles, the following paragraphs will analyze case studies that provide concrete examples of AR's application in sacred contexts, allowing us to explore the design choices made and the solutions implemented to balance technological opportunities with respect to the liturgical context.

1.4 Existing Applications and Case Studies

The following studies provide a comprehensive overview of the technological, design, and cultural aspects of the potential and critical issues related to the integration of AR with religious heritage. This paper will analyze each case, highlighting its design contributions, the influences on the user experience, and the implications for conservation, cultural mediation, and dialogue with religious communities. The three case studies selected for their demonstrative value are:

1. “Intelligent Cathedrals: Using Augmented Reality, Virtual Reality, and Artificial Intelligence to provide an Intense Cultural, Historical, and Religious Visitor Experience” by Oihab Allal Chérif (2022). It analyzes the application of AR, Virtual Reality (VR), and Artificial Intelligence (AI) in three cathedrals (Notre Dame, Exeter, Seville), demonstrating how these technologies can preserve accessibility and foster a profound spiritual and cognitive experience;

2. “Photogrammetry and Augmented Reality to Promote the Religious Cultural Heritage of San Pedro Cathedral in Guayaquil, Ecuador” by Joe Llerena Izquierdo and Luiggi Cedeño Gonzabay (2020). It presents the use of photogrammetry and AR via the mobile app “My Cathedral” to enhance and convey the local religious heritage;

3. “An Augmented Reality Application for the Frescoes of the Basilica of Saint Catherine in Galatina” by De Luca V., Corchia L., Gatto C., Paladini G., De Paolis L. (2022). It shows the development of an AR application designed to enhance and visually reconstruct the damaged frescoes in the Basilica of Saint Catherine, Galatina;

4. “Santa Croce in Extended Reality (XR)” by the Opera di Santa Croce in collaboration with TIM Enterprise, Qualcomm, and Live Reply. It is an innovative project that integrates immersive technologies to enrich visits, allowing visitors to interact with historical and artistic content through personalized, multisensory experiences;

5. “HeritageSite AR: An Exploration Game for Quality Education and Sustainable Cultural Heritage” by Ningning Xu, Jiachen Liang, Kexiang Shuai, Yuwen Li, and Jiaqi Yan. It developed an AR mobile app designed to offer an immersive and playful exploration experience at cultural heritage sites, combining interactive narratives and educational content to enhance enjoyment;

6. “Duomo 4.0” by Veneranda Fabbrica. It is a technological initiative that uses AR and virtual reality to offer visitors an immersive and interactive experience of Milan’s main cathedral, enhancing its history, art, and sacred spaces through innovative digital content.

1.4.1 Intelligent Cathedrals: integrated application of AR in European sacred places

The “Intelligent Cathedrals” project, previously mentioned, is one of the most advanced attempts at synergistic integration between AR, VR, and AI applied to enhance European sacred contexts. The primary objective of the initiative is to improve the cultural, historical, and religious experience of visitors while maintaining a design balance that preserves the liturgical and spiritual functions of the places. It has been implemented in several notable cathedrals, including Notre Dame de Paris, Exeter Cathedral, and Seville Cathedral.

The project has integrated digital heritage conservation features through the three-dimensional modeling of spaces and frescoes, the production of augmented iconographic content, and the interactive management of information via apps. Thanks to these tools, it is possible to document the current state of the works and virtually reconstruct architectural or decorative elements that have been lost or damaged, thus offering a concrete contribution to protection and restoration interventions.

Moreover, as previously observed, particular attention was paid to the distinction between liturgical and tourist moments in order to avoid interference between the devotional experience and that of the visit. This balance was achieved through flexible design solutions, which include time windows and areas physically dedicated to the activation of AR content. Indeed, “Intelligent Cathedrals” represents an advanced application model that demonstrates the possibility of integrating technological innovation with respect for sacredness while promoting a more immersive and conscious use of European religious heritage.

Figure 8 - AR App by Cathedral of Exeter

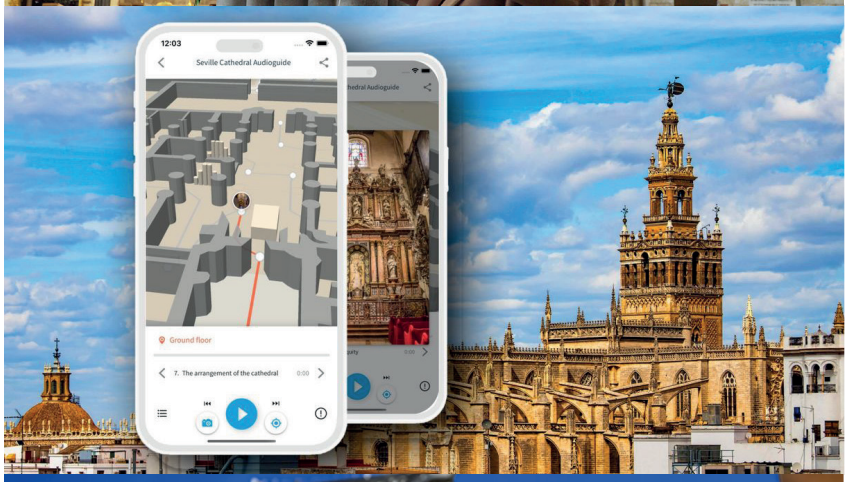


Figure 9 - AR App by Cathedral of Sevilla

FIgure 10 - AR App by Cathedral of Notre Dame, Paris

1.4.2 San Pedro Cathedral in Guayaquil: Photogrammetry and AR for Religious Heritage

The project developed by Llerena-Izquierdo and Cedeño-Gonzabay (2019) at San Pedro Cathedral in Guayaquil, Ecuador, represents a concrete application of the potential offered by photogrammetry integrated with AR for enhancing religious cultural heritage. The initiative led to the development of the "My Cathedral" mobile app, designed to offer visitors an augmented and accessible experience, facilitating the understanding of the artistic and architectural contents present in the cathedral.

Through the high-definition photogrammetric survey, the project enabled the acquisition of precise data for the three-dimensional modeling of sacred spaces, generating digital reconstructions of the most significant architectural and decorative elements. The AR content, which can be activated via mobile devices, provides visitors with contextual information, iconographic details, multimedia narrations, and historical insights, thereby enhancing their understanding of the symbolic meaning of the works and the liturgical rites associated with them.

Similarly to the previously mentioned projects, attention was paid to maintaining respect for the religious function of the place by developing the app as a complementary support to the devotional path without interfering with the ongoing liturgical practices. Therefore, the project demonstrates how AR can contribute to both educational and touristic enrichment, as well as to the conservation documentation of the ecclesiastical heritage.

Figure 11 - San Pedro Cathedral in Guayaquil

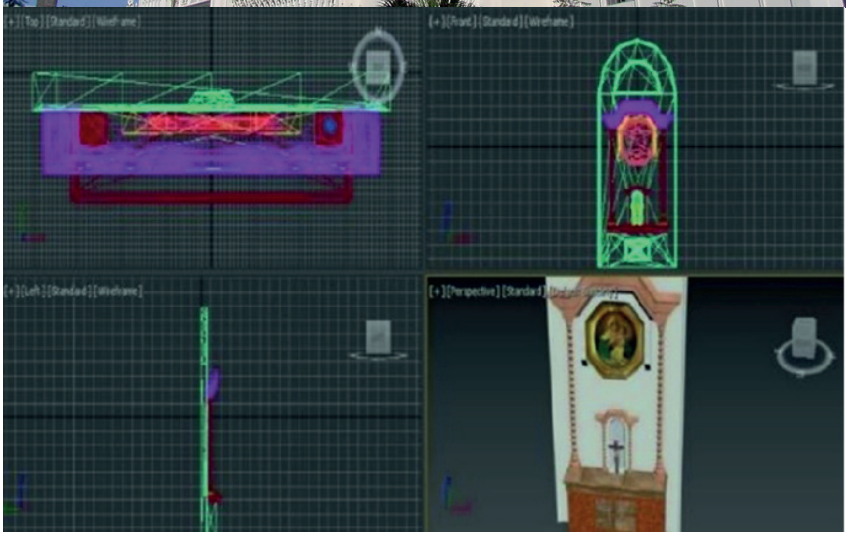


Figure 12 - Photogrammetry in the Cathedral of San Pedro

1.4.3 The Basilica of Santa Caterina in Galatina: AR for the enhancement of frescoes

De Luca et al., in the project concerning the Basilica of Santa Caterina in Galatina, present a targeted application of AR aimed at optimizing and perceptually recovering the fourteenth-century frescoes present within the monumental complex. The intervention is part of a context aimed at protecting partially deteriorated works, with the intention of offering visitors a visual reconstruction that can restore the original iconographic and chromatic complexity of the decorations.

The AR application helps people to directly frame the pictorial surfaces with their mobile devices, displaying digital overlays that virtually reconstruct portions of the fresco eroded by time and now no longer legible. In this way, the visit experience is improved by a narrative path that guides the user through the iconographic and theological understanding of the depicted scenes. In addition to enriching cultural enjoyment, the project has significant implications for digital preservation, providing valuable three-dimensional documentation for the exploration, restoration, and archiving of religious pictorial heritage.

In conclusion, the intervention conducted in the Basilica of Santa Caterina is a significant example of the ethically aware application of AR in sacred contexts. The project has demonstrated once again that this technology enables people to appreciate the religious pictorial heritage, in this case, which has been compromised by time, providing visitors with a comprehensive iconographic reading without compromising the devotional atmosphere of the place.

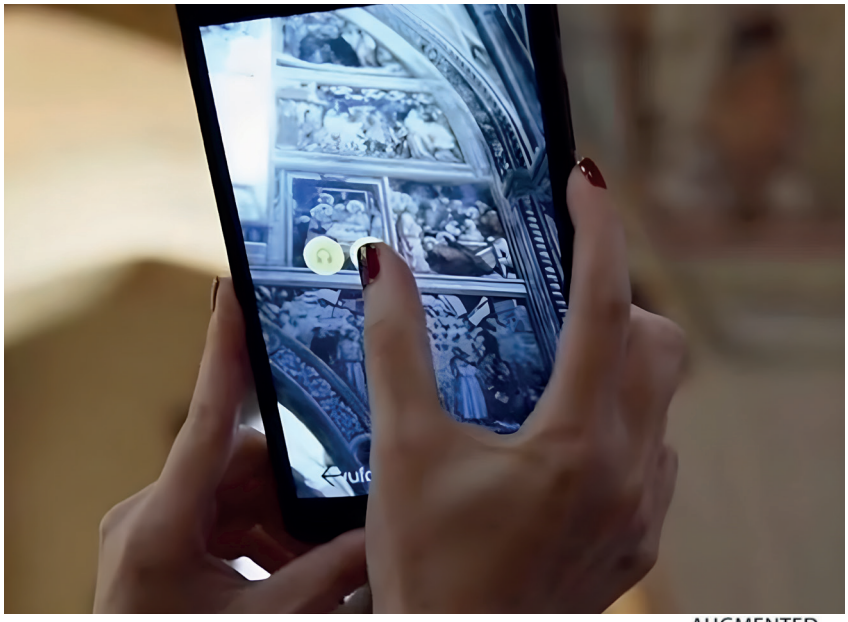


Figure 13 - Use of the application of the Basilica of Santa Caterina in Galatina

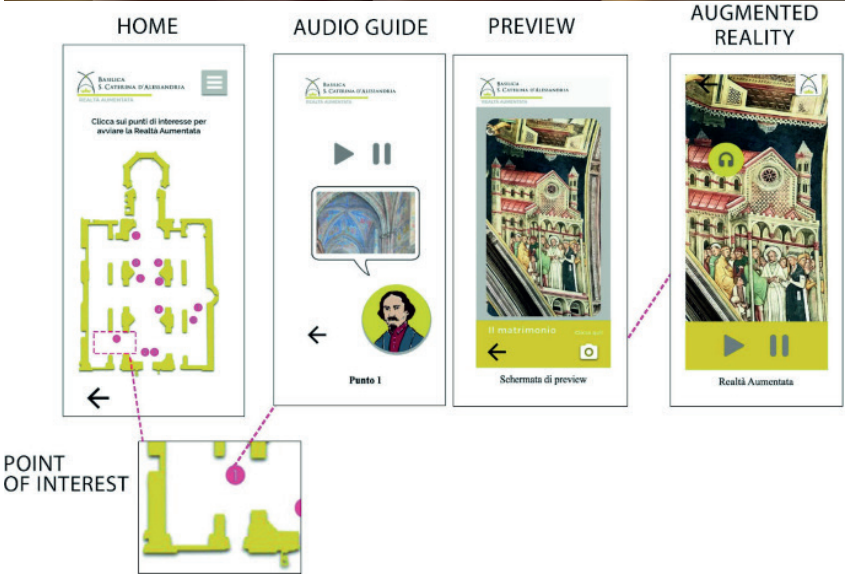


Figure 14 - Mock-up of the application of the Basilica of Santa Caterina in Galatina

1.4.4 Santa Croce in Extended Reality Project

The Santa Croce in Extended Reality project, managed by the Opera di Santa Croce in collaboration with TIM Enterprise, Qualcomm, and Live Reply, features two distinct itineraries. The "Greats of Santa Croce" itinerary utilizes immersive images and videos to bring figures such as Dante, Machiavelli, and Galileo to life alongside their tombs. On the other hand, "The Franciscan Path" allows visitors to virtually explore the frescoes and architecture linked to the history of the Franciscan order. The experience, accessible via 5G mmWave smartphones, integrates AR devices with traditional guides, offering an interactive narrative that enriches but does not replace a devotional visit, respecting the spaces and sacred nature of the complex.

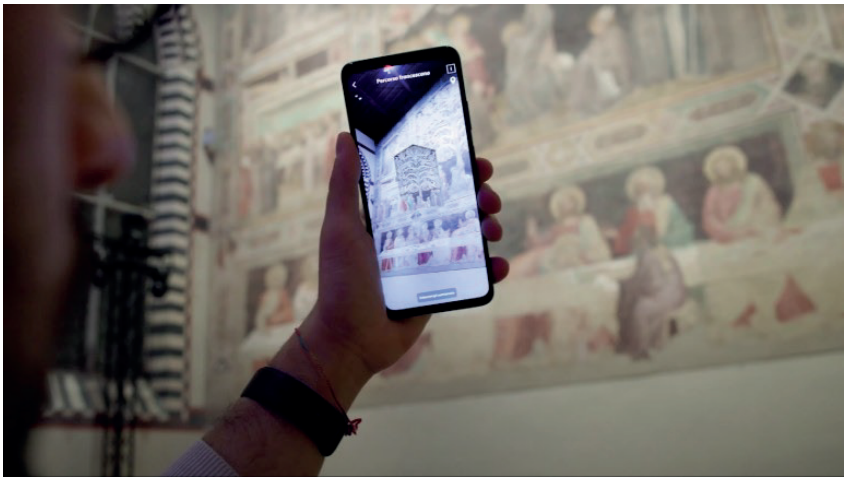
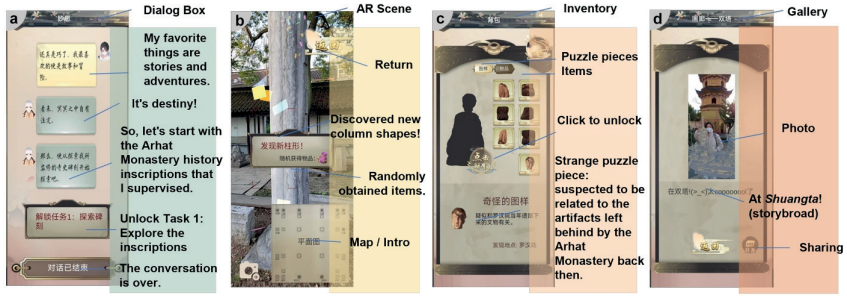


Figure 15 - Usge of Santa Croce Church AR App

1.4.5 HeritageSite AR: An Exploration Game for Quality Education and Sustainable Cultural Heritage

The HeritageSite AR project, developed by Xu et al. (2024), is a mobile app that transforms a visit to the Chinese site of the Arhat Monastery Remains and the Double Pagoda into a gamified AR experience. Through an interactive narrative, the app stimulates exploration of the site and understanding of its spiritual history, generating positive feedback from users. Experimental evaluation showed significant improvements in engagement and learning ability, demonstrating that the AR gaming component can foster an educational and sustainable experience of religious heritage without compromising the emotional depth of the site.



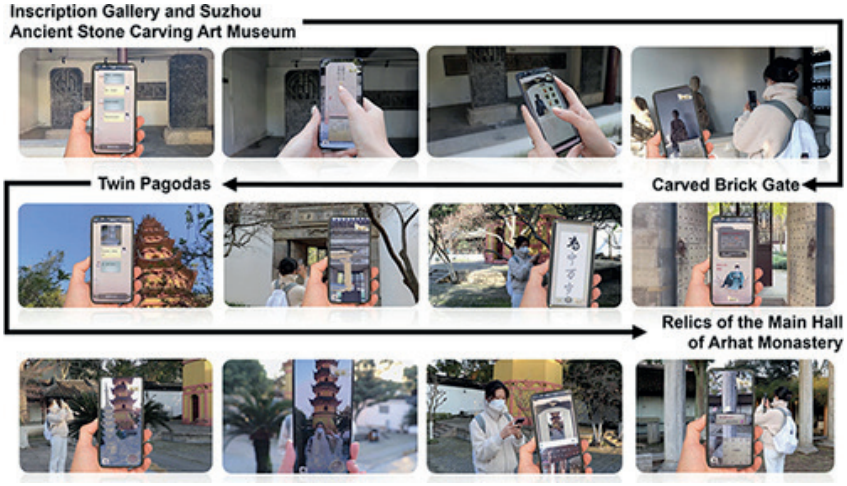


Figure 16 - Logical architecture of HeritageSite AR App

Figure 17 - User flow and user experience of HeritageSite AR App

1.4.6 Duomo 4.0 Project

The Duomo 4.0 program, launched by Veneranda Fabbrica, offers two complementary digital experiences: a virtual tour of the early stages of marble production in Candoglia and an AR smartglass tour of the Duomo Terraces. The first uses VR headsets at the Duomo Museum to recreate the marble quarrying site, while the second overlays images, videos, and historical details during a walk on the terraces, revealing otherwise unseen structures. This technological integration serves as an immersive support for the visit, facilitating understanding of the material and architectural context without altering the sacred nature of the site.

Figure 18 - Usage of AR Glasses in Church of Duomo of Milan, Italy

1.4.7 Comparison and summarize

The analysis of the case studies examined highlights heterogeneous approaches to the use of AR in places of worship and religious sites. The projects share the goal of facilitating understanding of artistic content, but differ significantly in several aspects, including:

Technology and infrastructure needed

One of the most critical aspects concerns the cost and complexity of the required infrastructure. Projects such as Santa Croce XR and Duomo 4.0 use advanced technologies (5G mmwave, headsets, smartglasses), with a high degree of immersion and interactivity. However, this entails higher implementation costs and a reliance on dedicated devices that are not always compatible with the liturgical context. In contrast, HeritageSite AR and Galatina AR adopt solutions based on personal devices (smartphones and tablets), reducing the access threshold and promoting system scalability, although at the expense of some of the immersive impact.

Accessibility and inclusiveness

Projects based on mobile apps, such as My Cathedral and HeritageSite AR, are particularly effective in ensuring access to diverse audiences. This is thanks to compatibility with popular smartphones and the ability to integrate multilingual content, audio or visual descriptions, and simplified interfaces. In the case of the Cathedral of San Pedro in Guayaquil, the application features a guided narrative structure that improves usability even for users with visual or linguistic impairments. On the other hand, experiences like Santa Croce XR and Duomo 4.0, while offering highly immersive and innovative content, have limitations due to the need for dedicated devices (such as VR headsets or AR glasses), which reduce their affordability and ease of use, especially for audiences with less technological expertise or sensory disabilities.

User involvement and stimulation

The level of engagement varies significantly between projects. HeritageSite AR, thanks to its playful and gamified component, achieves a high degree of active participation, stimulating interaction and content memorization. Intelligent Cathedrals also offers a strong emotional narrative, but maintains a more contemplative and reflective tone, consistent with the sacredness of the sites involved. Duomo 4.0, on the other hand, falls somewhere in between, introducing immersive elements without compromising the balance between tourism and religious functions.

Innovation and replicability

In terms of innovation, Santa Croce XR represents one of the most technologically advanced experiments, thanks to the integration of extended reality, AI, and 5G networking. However, replicability in other contexts is limited due to the high resources required. More replicable are models based on mobile apps like Galatina AR or HeritageSite AR, which can easily be adapted to other contexts with similar artistic heritage.

Project Expansion

Projects like Intelligent Cathedrals and Galatina AR have shown a particular propensity for scalable expansion, both geographically and in terms of content. The ability to map new churches, frescoes, or iconographic itineraries makes them suitable for inclusion in interregional promotion networks. Contrarily, applications like Duomo 4.0 seem designed to remain limited to a specific architectural context.

Support for cultural mediation and educational impact

All projects share an educational function but differ in their approach. Apps like My Cathedral or Galatina AR focus on accessible and simplified mediation, helpful even for non-experts. The Intelligent Cathedrals project, on the other hand, offers more layered content, designed to stimulate theological reflection even among the most knowledgeable visitors.

1.4.8 System innovation diagram

The System Innovation Diagram offers a comparative representation of the main Augmented Reality projects and applications developed for religious and sacred contexts. Using a dual-axis system, the graph ranks each initiative based on its degree of technological and narrative innovation (horizontal axis) and its ability to open new markets or transform the visitor experience (vertical axis). Thus, the diagram does not simply list individual applications, but highlights their relative position and strategic potential: from projects that improve existing tools to experiments that propose radically new user models. The map thus becomes a useful tool for understanding how different AR solutions are distributed across the international landscape, offering a clear picture of future trends and directions in which the sector can evolve.

Explore trasformative opportunities and radically new models

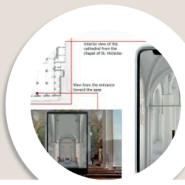
Create new markets targeting new customers

Enter adjacent markets

Serve better existing customers and markets

Use/improve existing products assets

Add increm
products and

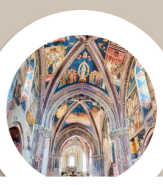


Intelligent Cathedrals

Santa Croce in XR

Duomo 4.0

thedral



AR App - Basilica di Santa Caterina

mental
d assets

Develop new products and assets

Go beyond products and customer narrative

02. FURTHER RESEARCH
Field research

2.1 Research objectives

After outlining the theoretical framework relating to the application of AR in sacred contexts, this part proposes to investigate the information needs, visiting behaviors, and critical issues encountered by visitors to less frequented churches in Rome. In particular, the research intends to:

1. Detect the current ways of enjoying the works of art kept in the selected sacred places;

2. Evaluate the level of effectiveness and accessibility of the information tools currently available on-site;

3. Identify the main difficulties encountered by visitors in the historical and artistic understanding of the works;

4. Analyze the interest of visitors in introducing solutions based on AR as a support for cultural mediation in religious contexts;

This empirical activity was developed following an integrated approach that combines different sources and methods. To collect various data, three methods were employed: first, structured questionnaires were administered to visitors; second, direct on-site observations were conducted to analyze visiting behaviors; and third, online reviews published on TripAdvisor regarding the churches visited in Rome were systematically examined.

2.2 Methodological strategy and mixed approach

In order to analyze in depth the complexities and problems related to the experience of visiting the less-known places of worship in Rome, the study adopted a methodological strategy based on a mixed approach (mixed method). This choice enables the integration of quantitative and qualitative data, providing a more comprehensive and detailed view of the phenomenon under study. In particular, the structured questionnaire allowed for the collection of standardized data on the perceptions expressed directly by visitors; on-site observations allowed for direct analysis of the behavioral dynamics of visitors during the use of sacred spaces; finally, the systematic analysis of online reviews provided an additional source for detecting critical issues and expectations. Indeed, this collection of data reconstructs a realistic picture of the information problems most frequently encountered in the places investigated. Moreover, the joint use of different methodologies allowed for the reduction of the limitations of the individual survey tools, improving the overall validity of the empirical evidence collected. The mixed approach has proven particularly effective in this area, where cognitive, emotional, practical, and symbolic dimensions are strongly intertwined.

2.3 Data collection

To detect the perceptions and information needs of visitors, a structured questionnaire was developed and administered to tourists visiting four churches in Rome: Basilica of Sant'Agostino, Santa Bibiana, Santa Maria della Pace, and San Francesco a Ripa. The selection of these places was made following a preliminary analysis conducted on TripAdvisor, which highlighted that these churches, despite housing frescoes by important artists such as Caravaggio, Raffaello, Michelangelo, and Bernini, are relatively less frequented and considered than other religious sites in the city.

2.3.1 Survey on Visitors

Figure 19 - Basilica of Sant'Agostino, Santa Bibiana, Santa Maria della Pace e San Francesco a Ripa

The questionnaire examined several dimensions relevant to the study's purposes. First, the demographic and tourist profiles of visitors were collected, including nationality, age, and frequency of visits to sacred places. Then, opinions on the usefulness of the on-site information tools, including descriptive panels, paper guides, audio guides, and the official website, were analyzed. A specific section examined the level of understanding of the works of art, specifically verifying the ability of visitors to decode the symbolic and historical content of the frescoes present. Particular attention was paid to the analysis of the difficulties related to accessibility and physical use of the spaces, due to architectural, structural and environmental issues. Finally, the questionnaire also explored participants' interest in introducing potential AR applications as information support during the visit. The use of both closed (Likert scale) and open-ended questions was helpful in collecting systematic, quantitative data but also acquiring qualitative indications that were useful for integrating the subsequent interpretative analysis.

2.3.2 On-site observation in hidden churches

In parallel to the administration of the questionnaire, direct observations were conducted inside the same churches in Rome previously listed. The purpose of this observation phase was to observe the spontaneous behaviors of visitors as they moved through the space and interacted with the artistic heritage. The following ethnographic analysis highlighted some recurring critical issues in the visiting experience. First of all, many visitors appear to have difficulty locating the main works within the churches, often due to a lack of clear signage.

Figure 22 - Examples of lack of clear signage

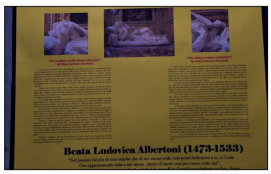
Indications of the works in the Basilica of Santa Maria sopra Minerva

Directions to Caravaggio in the Basilica of Sant'Agostino

In the absence of adequate information support, the frequent use of personal devices, such as smartphones, has emerged as a means to search for information independently. Furthermore, in several cases, visitors showed the need to ask for explanations from other people present or the ecclesiastical staff.

Figure 23 - Examples of lack of adequate information support

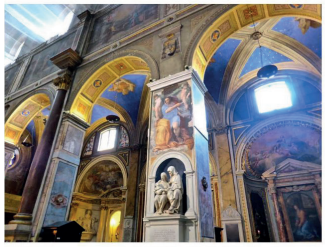
Descriptive panel of a Raphael in the church of Sant'Agostino



Bernini's statue with a few lines of description in the Church of San Francesco a Ripa

A further limitation concerns the visual enjoyment of the frescoes, in particular those placed in elevated or marginal positions, whose distance hinders direct observation and iconographic understanding.

Figure 24 - Examples of architectural barriers that make the visit experience difficult



Renovation of the Church of Sant'Agostino

Isaiah by Raphael difficult to notice in the interior of Santa Maria della Pace

The observation activity contributed to verifying and enriching the picture that emerged from the questionnaire, providing further evidence of the information gaps and visitor needs.

2.3.3 Analysis of TripAdvisor reviews

To complete the empirical framework, a qualitative analysis of the reviews published on TripAdvisor for the four selected sacred places was conducted. These reviews, posted spontaneously by visitors, provide an authentic source for understanding the recurring perceptions of tourists in the visit experience. The analysis focused on recurring keywords, such as “frustration,” “description,” “panel,” and “context,” to isolate observations pertinent to the visit experience.

The survey highlighted important critical issues across the board. Among the most repeated complaints, the poor lighting inside the churches stands out, which compromises the visibility of many works, in some cases exacerbated by the fact that visitors had to pay for the visit.

As one visitor observes, “some works in the church are dark and difficult to read the information.” Another aspect reported by numerous visitors is the presence of construction sites or restorations in progress that hinder the complete view of the frescoes or limit access to them. A significant number of reviews also complain about the total absence of descriptive panels, making it difficult to understand the iconographic meaning of the works and to place them in their historical context. For example, one review notes that “the numerous works inside do not contain adequate information tables. Those who visit the works of art by chance, without a guide, must limit themselves to observing.” Added to this is the problem of the lack of clear indications for locating the most important frescoes, which often turn out to be poorly reported. Overall, the analysis of the reviews confirms many of the critical issues that have already emerged in the questionnaire and the on-site observations, reinforcing the evidence of the need for new, more effective interpretative tools. Here are some excerpts from reviews:

Basilica of Sant’Agostino

- “What a shame, Caravaggio was illuminated by a dim light and for a short time.”

- “Some of the church works are dark and difficult to read the information.”

Basilica of San Francesco a Ripa

- “Unfortunately today the chapel was closed and therefore the statue could only be admired from a certain distance and with insufficient lighting.”

- “However, the church is not well organized... there are no signs that highlight Bernini's work... but it is worth a visit even just for one of the masterpieces.”

Basilica of Santa Bibiana

- “The lighting was minimal, and the two coin-operated lighting machines were broken. Naturally, we left after two minutes without being able to see anything. On the other hand, on winter days without lighting, there's no chance of seeing the frescoes.”

- “At least put up a sign, right? Shameful, superficial, and charlatan, a symbol of Rome. What a shame, what a disgrace, what a pain.”

Basilica of Santa Maria della Pace

- “Although I've spent some time reading about this masterpiece online, reading some users' comments, I've realized I've missed a lot of details. So I'll get back to it as soon as possible.”

- “Although I visited it in the middle of the afternoon when it was still light outside, the poor internal lighting made my visit particularly difficult, so much so that I was unable to fully enjoy the important works kept outside.”

2.4 Interpretation of results

The analysis of the questionnaire results highlighted three main aspects:

1. Recurring frustrations related to the visitor experience;

2. The limitations of the effectiveness and accessibility of the tools currently available on-site, which are often inadequate to meet the needs of a diverse audience;

3. Visitors' interest in AR solutions as a means of enhancing the experience of religious heritage.

These findings provide the basis for the subsequent definition of design scenarios aimed at creating a more accessible, engaging, and respectful experience of the sacred context.

2.4.1 Limitations of the visiting experience

The survey highlighted a series of critical issues that hinder the full appreciation of religious heritage. These difficulties manifest themselves along three dimensions: informational, physical, and cognitive. In terms of information, 68% of visitors stated that they found no descriptive support whatsoever within the churches they visited. In particular, many users complained about the lack of explanatory panels near the works and the lack of multilingual content. A recurring comment in online reviews emphasized: "I would have appreciated a few more explanatory panels, or the opportunity to listen to a guide." Physical barriers represent a further obstacle. 42% of visitors reported difficulties related to insufficient lighting, while 31% indicated the presence of scaffolding obscuring frescoes or limiting access to areas.

Figure 25 - Example of a poor information panel in Basilica of Sant'Agostino

Physical barriers represent a further obstacle. 42% of visitors reported difficulties related to insufficient lighting, while 31% indicated the presence of scaffolding obscuring frescoes or limiting access to areas.

Figure 26 - Example of scaffolding in the Basilica of Sant'Agostino which hinders the normal visiting experience

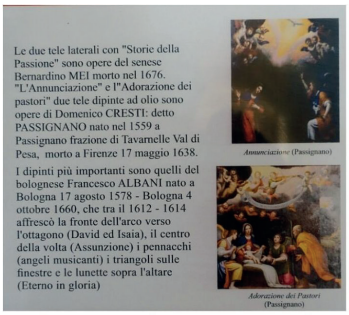
Finally, cognitive difficulties emerged: 59% of users admitted not fully understanding the symbolic meaning or historical context of the works. This difficulty was often accompanied by the need to ask ecclesiastical staff for information. The visit experience was poorly mediated and fragmented in terms of interpretative accessibility. Indeed, the data underscore the urgent need for tools to improve the quality of the experience in sacred places.

2.4.2 Critical issues of traditional information mediation

The research highlighted how the tools currently available on the sites fail to meet the needs of a contemporary audience. Only 27% of visitors stated that they found the on-site information devices sufficiently clear and comprehensive. The most common forms of mediation, such as wall panels or brief paper descriptions, are often perceived as too concise. Many visitors cited the lack of content accessible in multiple languages as a significant barrier. This situation is confirmed by 62% of the foreign tourists interviewed, who expressed a desire for easily accessible multilingual content during their visit.

During the on-site analysis of the selected churches, several information tools with varying degrees of effectiveness and diffusion were identified. The most common form found was explanatory panels, generally located near the works or at the entrances to the naves. These panels provide basic information about the author, the historical period, and the subject represented, typically presenting themselves as rigid wooden or metal supports with printed text, and in some cases, accompanied by images or diagrams. Their main function is to convey synthetic and standardized information, useful for initial orientation, but rarely enriched by critical insights, bibliographical references, or multilingual translations.

Figure 27- Examples of information panels near the frescoes in the church of Sant'Agostino

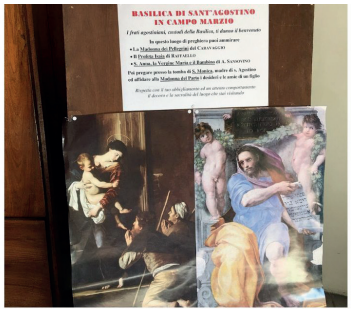

Le due tele laterali con "Storie della Passione" sono opere del senese Bernardino MEI morto nel 1676. "L'Annunciazione" e l'"Adorazione dei pastori" due tele dipinte ad olio sono opere di Domenico CRESTI detto PASSIGNANO nato nel 1559 a Passignano frazione di Tavarnelle Val di Pesa, morto a Firenze 17 maggio 1638.

I dipinti più importanti sono quelli del bolognese Francesco ALBANI nato a Bologna 17 agosto 1578 - Bologna 4 ottobre 1660, che tra il 1612 - 1614 affrescò la fronte dell'arco verso l'ottagono (David ed Isaia), il centro della volta (Assunzione) i pennacchi (angeli musicanti) i triangoli sulle finestre e le lunette sopra l'altare (Eterno in gloria)

Annunciazione (Passignano)

Adorazione dei Pastori (Passignano)

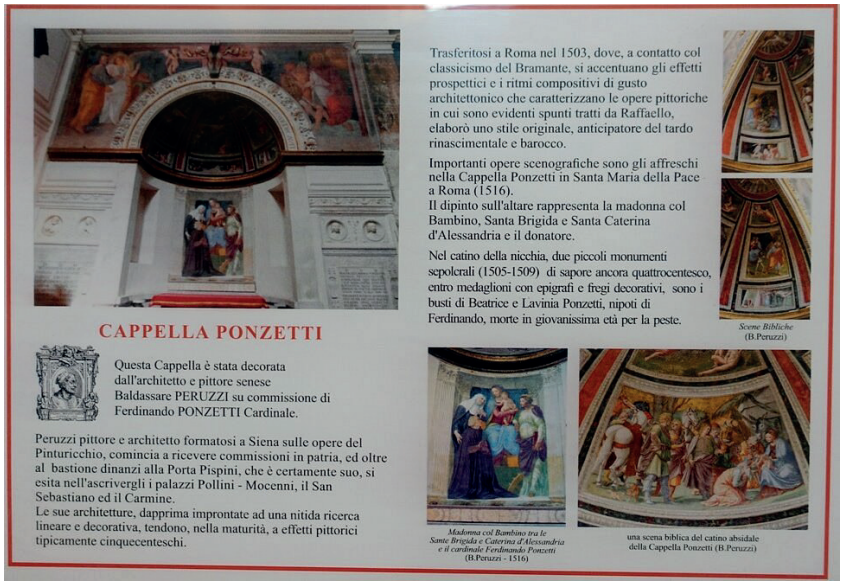
Sparse descriptions in the church of Sant'Agostino



Artworks by Caravaggio and Raphael in the Church of Sant'Agostino without descriptions

In some cases, the presence of paper brochures has been observed, offering a more detailed description of the artistic heritage, often structured as small folding booklets containing more extensive texts, photographs, church maps, and suggested visit routes. The brochures have the advantage of being able to be carried with you during the visit and consulted freely, but they are only available in a limited number of copies and in a few languages, thus reducing their usability for a heterogeneous audience.

Figure 28- Examples of a brochure for the Ponzetti Chapel in Santa Maria della Pace



Additionally, some churches provide audio guides, although availability is limited and content is often standardized. These devices generally consist of small portable devices with headphones, which play audio recordings divided into tracks corresponding to the various works or sections of the church. The audio guide provides verbal explanations of a historical-artistic nature and sometimes narrative anecdotes, offering a more immersive approach than the simple written panel. However, the experience remains inflexible: the contents follow a pre-established path and do not allow the visitor to select the level of detail or freely delve into the aspects of greatest interest.

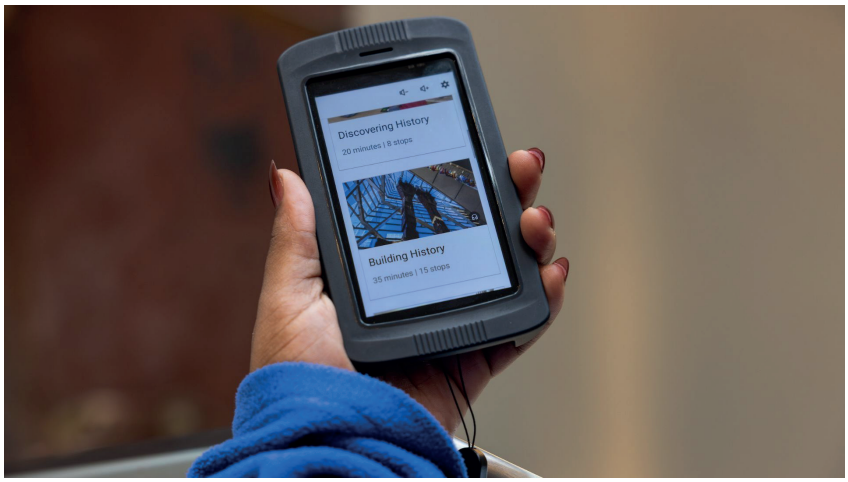


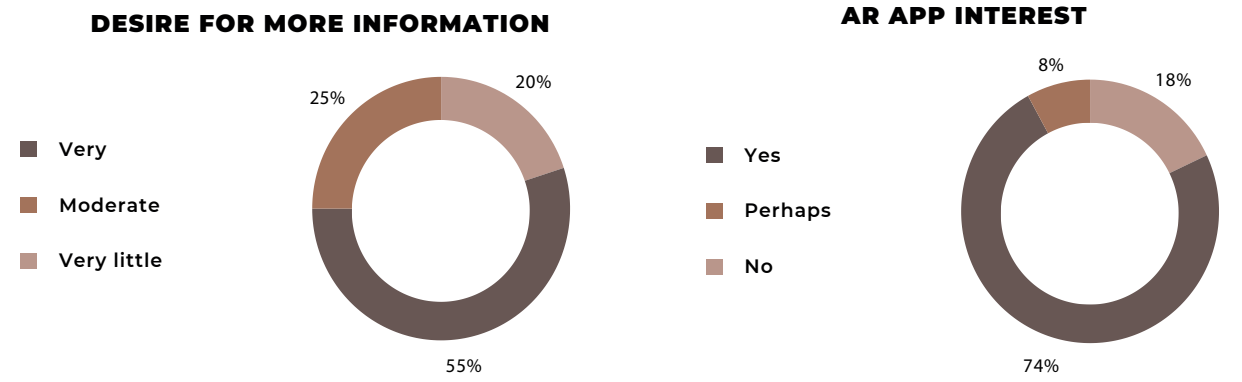
Figure 29- Example of church audio guide

Traditional tools often prove insufficient to effectively guide visitors in understanding the work, making it difficult for them to grasp the iconographic, artistic, and spiritual value of religious heritage.

2.4.3 AR as an opportunity perceived by visitors

The research revealed strong interest in technological solutions that can improve the understanding and enjoyment of religious heritage. Specifically, 74% of respondents stated that an AR application would make the visit experience more engaging and informative. Among the most requested features were the ability to view reconstructions of damaged frescoes (52%), activate multilingual audio narrations (58%), and zoom in on iconographic details with contextual explanations (63%). Some visitors also suggested the inclusion of a virtual assistant or artist avatar that could directly "narrate" the work, contributing to a more immersive experience. Despite the general interest, 18% of respondents expressed concerns related to privacy or the use of their device's camera.

Therefore, AR presents a concrete opportunity to renew cultural mediation in sacred places, provided that the adoption of these technologies respects the symbolic and spiritual context that characterizes them.



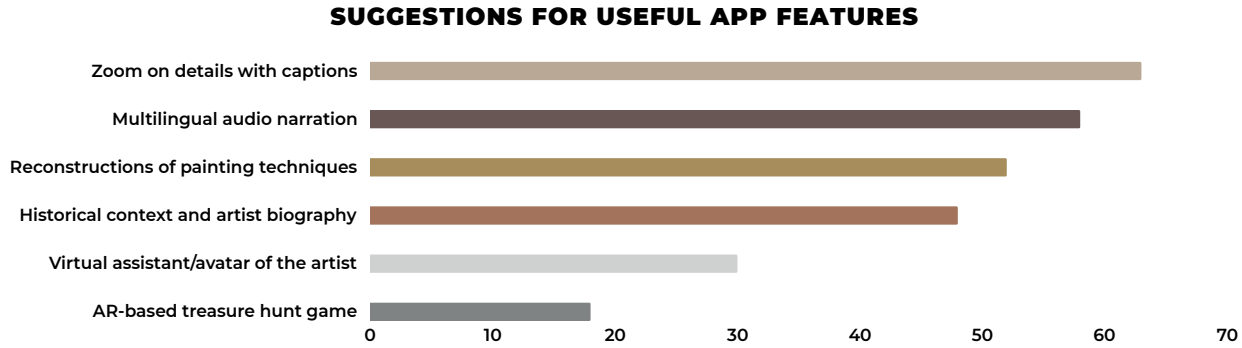
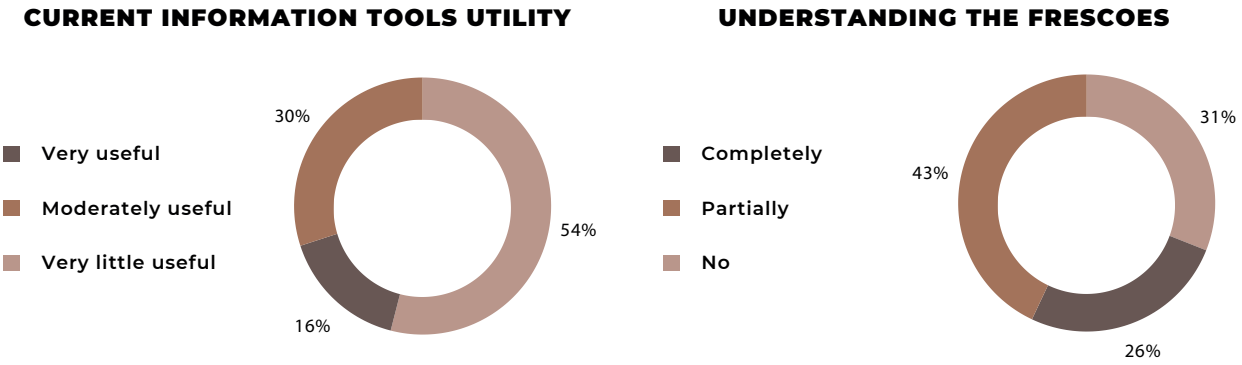


Figure 20 - Survey results pt.1



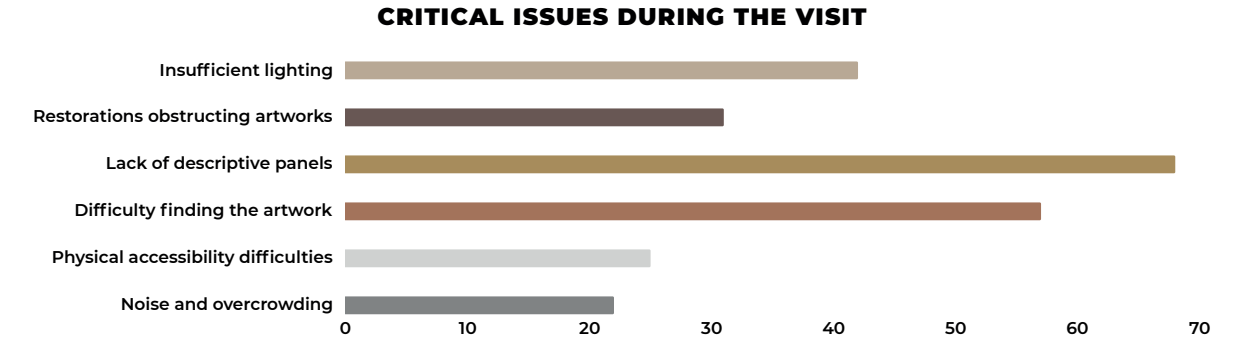


Figure 21 - Survey results pt.2

03. IDEATION

3.1 Insight and Problem

The analysis conducted during the research phase revealed a central insight, a cornerstone of the conceptualization phase. While appreciating the artistic and spiritual value of the frescoes, visitors to Rome's less-frequented churches often experience an incomplete experience.

The critical issues identified, including poor physical visibility of the works, the absence of descriptive panels, a lack of historical and iconographic context, and a language barrier, translate into an experience that risks being visually interesting but culturally superficial.

At the same time, the empirical study shows a high level of openness among visitors to the adoption of digital tools that can support their understanding of the works, including Augmented Reality. From this evidence, the project question arises:

"How can Augmented Reality become an effective and respectful tool for cultural mediation in Rome's lesser-known places of worship?"

Ongoing

Lack of adequate descriptions of the works

Understanding the meaning

Exp

Unclear context

Difficult religious symbols

Information not translated

Cognitive Pains

Multilingual

Respectful

Symbol decoding

Context-aware

Aug

R

Lack of tools to enhance the religious heritage

Further information on request

Fu

Digital r

g involvement

eriential
Needs

Personalised
experience

Lack
of personalized
and immersive
supports

Immersive

accessible

umented
Reality

Non-invasive

Visual
restoration

Practical
Pains

Poorly visible
Art-works

Panels absent
or not clear

Inaccessible
areas

nctional
Needs

Multilingual
content

Lack of signage
and visual
orientation

econstruction

3.2 Personas

To orient the project toward real user needs, two representative profiles were identified: Thomas and Flavia. They reflect two different but complementary ways of experiencing visiting Rome's sacred spaces.

Thomas, a young international student, is driven by a cultural and visual interest. He loves discovering and documenting frescoes, despite not having a direct connection to religion.

Flavia, a Roman office worker, is deeply connected to the spiritual dimension. She visits churches to pray and find inner balance, but she also nurtures an interest in the history and beauty of sacred places.

These two archetypes allow us to cover a broad spectrum of potential users: those who approach churches with a curious and secular perspective and those who visit for spiritual and personal reasons. The application we designed aims to meet the needs of both, offering an informative, respectful, and customizable experience.

"I love getting lost in the streets of Rome
church has a story to tell. I'm curious abou

MAIN POINT

Name: Thomas Thuram

Age: 24 Years old

Nationality: French

Occupation: Student

Hobbies: Urban sketching, photography

Personality: Curious, analytical, independent

PROFILE

Thomas is in Rome for
in Art History. He's thou
loves exploring the city
notebook and a camer
symbolic places, like ch
often visits to observe f
architectural details. Al
believer, he's fascinated
meaning behind sacre

ACTIVITIES

1. During the week, he attends university classes;
2. On his free afternoons, he strolls around the city listening to podcasts or taking photos;
3. He occasionally enters small, uncrowded churches to quietly observe the architecture and atmosphere;
4. On weekends, he visits tourist neighborhoods in search of architectural details to sketch in his notebook.

QUESTIONS

1. Am I truly understa
or am I just observir
2. How can I continue
feeling overwhelme
3. Am I able to find a b
need for solitude an
connection?
4. Are my experiences
person, or am I just

and discovering hidden corners. Every fresco, every
ut all religions: through art, I can feel closer to them."

an Erasmus program
ughtful, curious, and
alone, with a
a. He enjoys quiet,
urches, which he
frescoes and
lthough he's not a
d by the hidden
d images.

nding what I'm seeing,
ng the surface?

to learn without
ed by the information?

balance between the
nd the desire for

enriching me as a
following safe habits?

GOALS

1. Cultivate a deeper understanding of the world around them;
2. Maintain a calm and reflective lifestyle, without sacrificing discovery.
3. Continue to nourish their curiosity with new experiences and places to explore;
4. Experience the moment in a personal, silent, and respectful way.

PAIN

1. Tends to isolate himself during moments of intense concentration, neglecting social interaction;
2. Sometimes feels overwhelmed by the desire to fully understand everything, resulting in overanalyzing experiences;
3. Feels excluded from deeper meanings due to a lack of cultural and religious context;
4. Has difficulty distinguishing what is truly important to observe in works of art.

"Faith is a cornerstone of my family life. I
sacred places: they hold stories that stren

MAIN POINT

Name: Flavia Condotti

Age: 42 years old

Nationality: Italian

Occupation: Administrative Clerk

Hobbies: Walking in historic neighborhoods, reading, amateur photography

Personality: Thoughtful, respectful

PROFILE

Flavia lives in Rome wi
works as a clerk in a pu
balanced and orderly l
faith, and a work routi
thoughtful, and attach
values. She has a stron
and maintains stable, a
relationships with fam
simplicity is a conscio

ACTIVITIES

1. During the week, she works in the office and takes care of the house with her husband.
2. On weekends, she visits spiritual sites in the city, even the lesser-known ones.
3. She loves strolling through the historic neighborhoods, taking photos, and stopping to read plaques or texts.

4.Once a month, she participates in community events, such as special masses or local religious gatherings.

QUESTIONS

1. Am I still able to car
true calm in my rou
2. Am I passing on the
to the new generati
3. What can I do to ma
with the most auth
4. Am I still able to fee
merely formal, spirit

attend church regularly, but I also love discovering other
ngthen my connection to my roots."

th her husband and
ublic office. She leads a
ife, built around family,
ne. She is calm,
ed to traditional
g sense of community
affectionate
ily and friends. For her,
us choice.

GOALS

1. Maintain a balanced life between spirituality, work, and personal time;
2. Find moments of peace and reflection in the places you visit;
3. Continue to discover hidden corners of the city linked to faith and history;
4. Strengthen your connection with religion through authentic experiences.

rve out moments of
tine?

e value of these places
ions?

aintain my connection
entic part of my city?

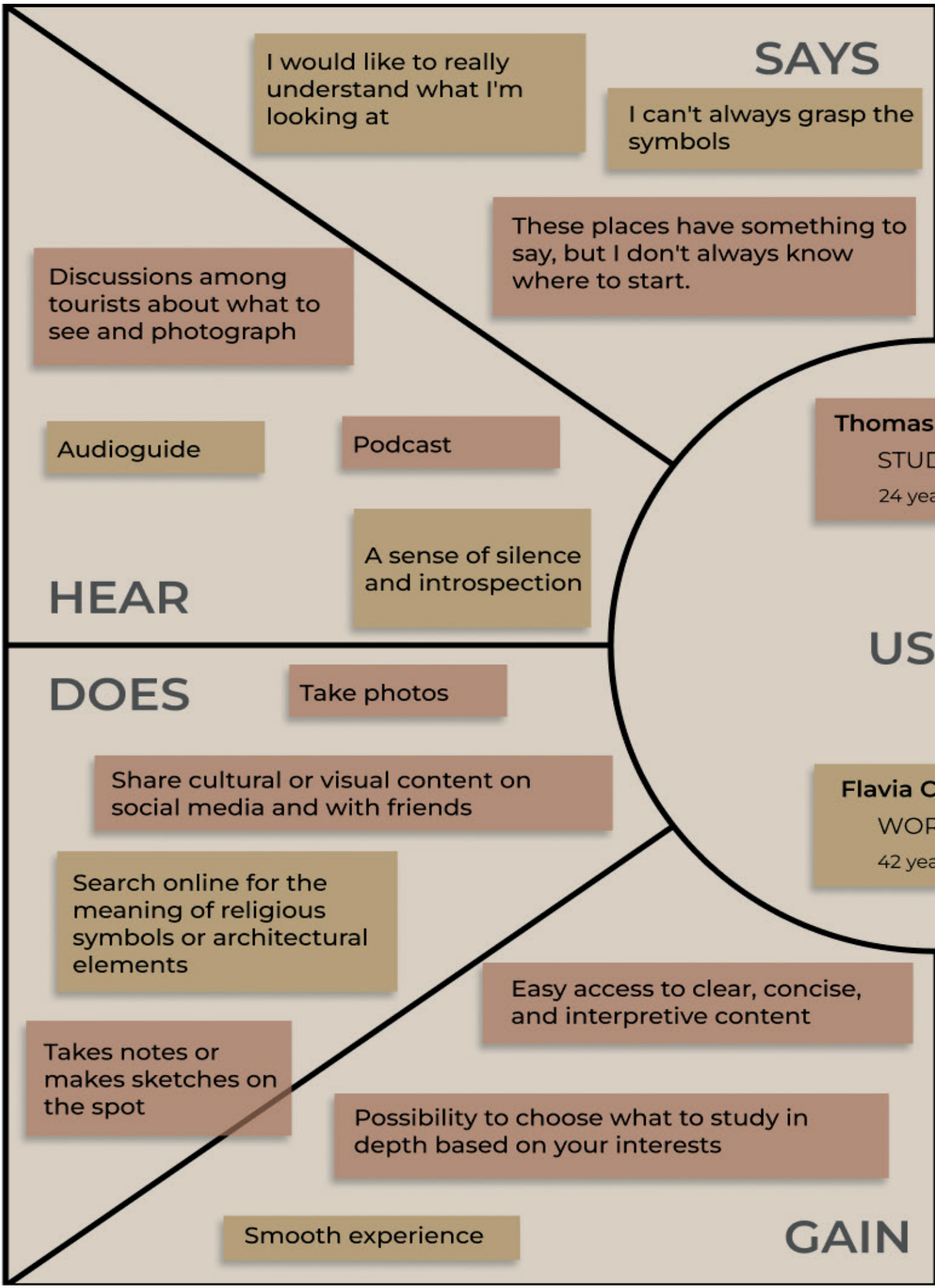
l part of a living, not
tuality?

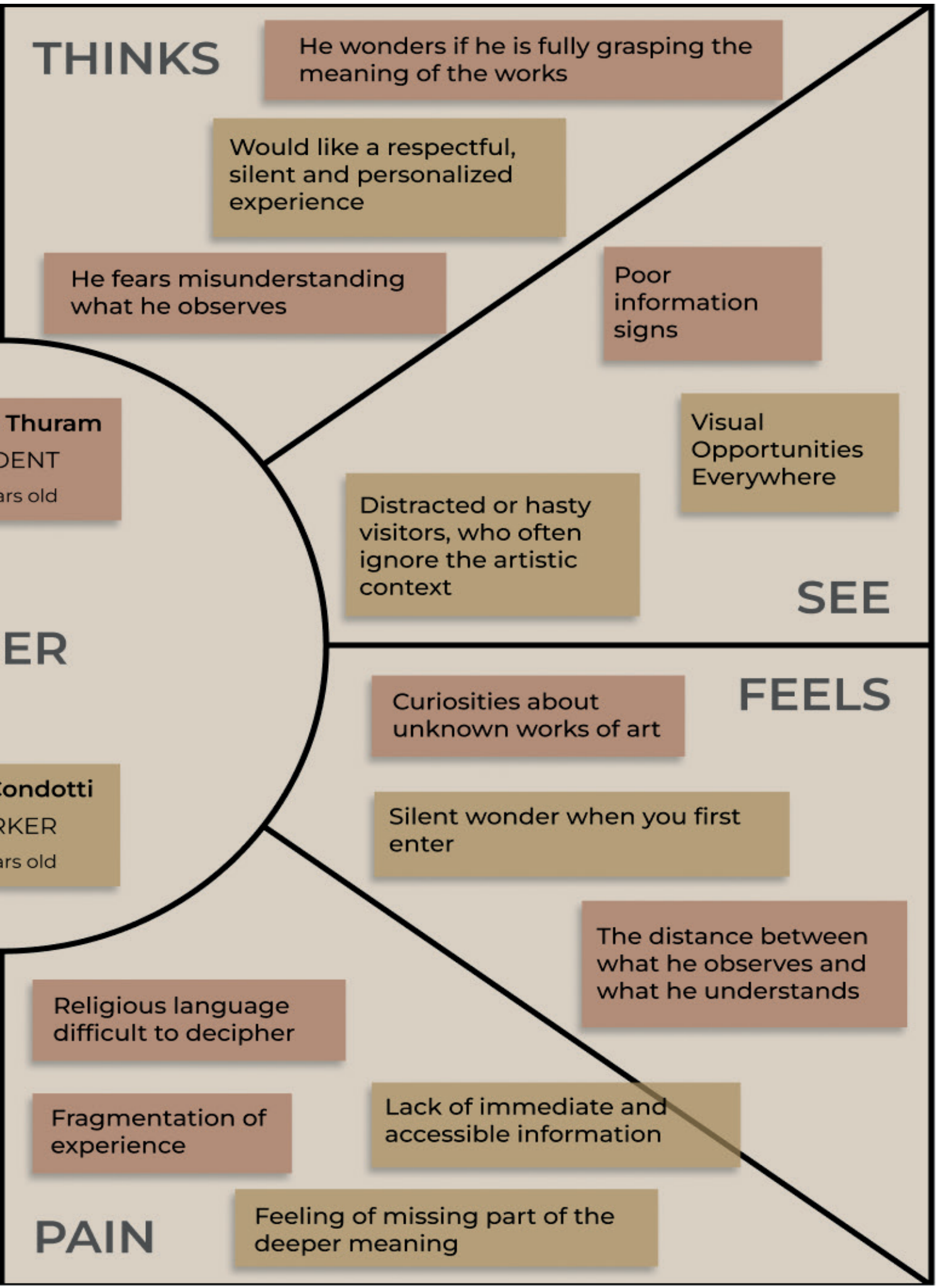
PAIN

1. She sometimes struggles to find spiritual places free from the tourist crowds;
2. Information about religious works is often technical or difficult to access;
3. She feels disoriented when there's a lack of clear information about the history of what she observes;
4. She longs for deeper experiences, but often lacks the time or adequate tools.

3.3 Empathy Map

To better understand users' needs, emotions, and behaviors, an Empathy Map was created that integrates the perspectives of the two primary personas identified. The goal is to summarize what users see, think, feel, say, and do, highlighting areas of frustration (pain) and unexpressed desires (gain), thus guiding design decisions toward a more focused experience.

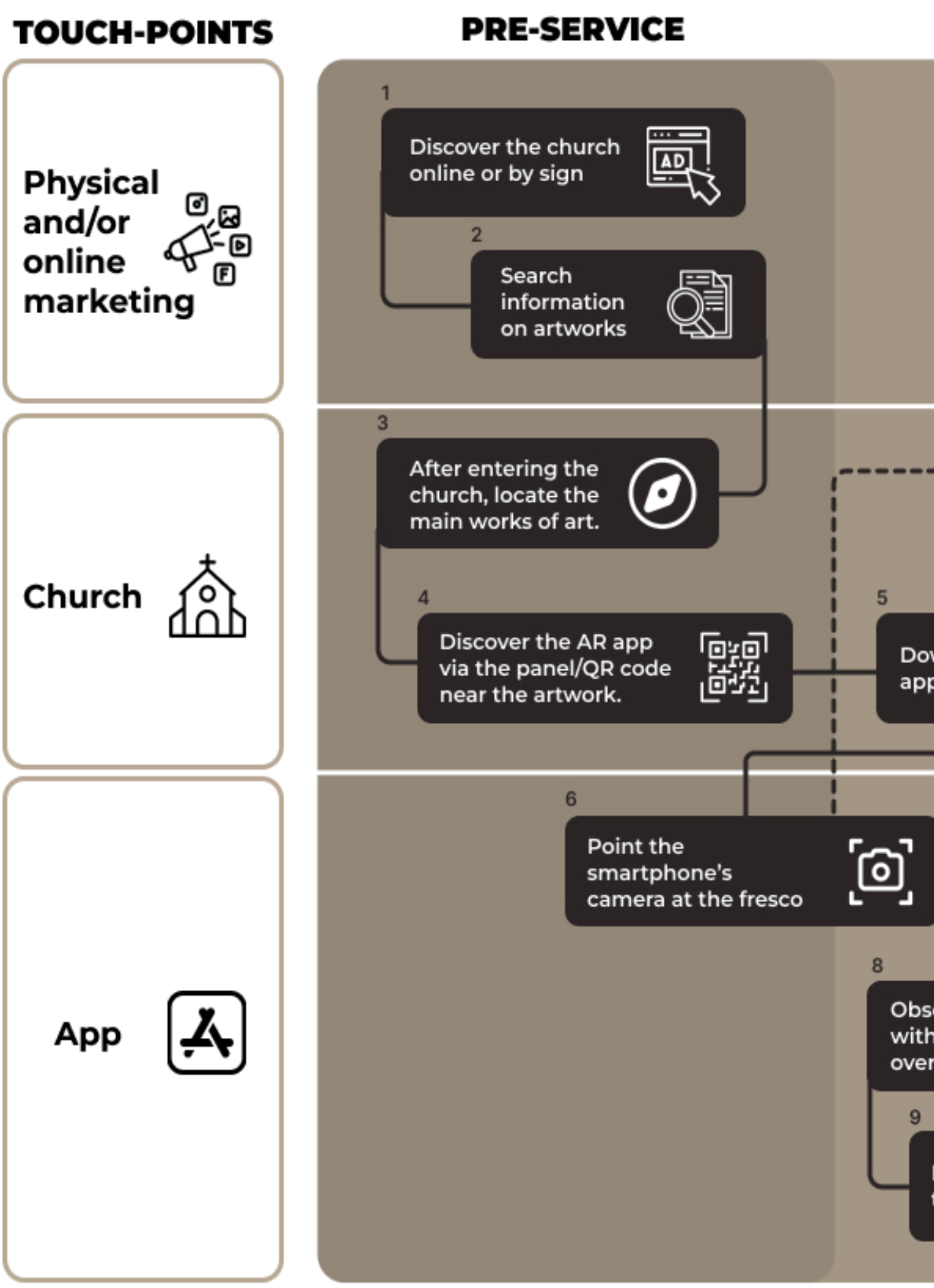

SAYS
I would like to really understand what I'm looking at
I can't always grasp the symbols
These places have something to say, but I don't always know where to start.
Discussions among tourists about what to see and photograph
Audioguide
Podcast
A sense of silence and introspection
HEAR
Thomas
STUD
24 yea
US
DOES
Take photos
Share cultural or visual content on social media and with friends
Flavia C
WOR
42 yea
Search online for the meaning of religious symbols or architectural elements
Easy access to clear, concise, and interpretive content
Takes notes or makes sketches on the spot
Possibility to choose what to study in depth based on your interests
Smooth experience
GAIN

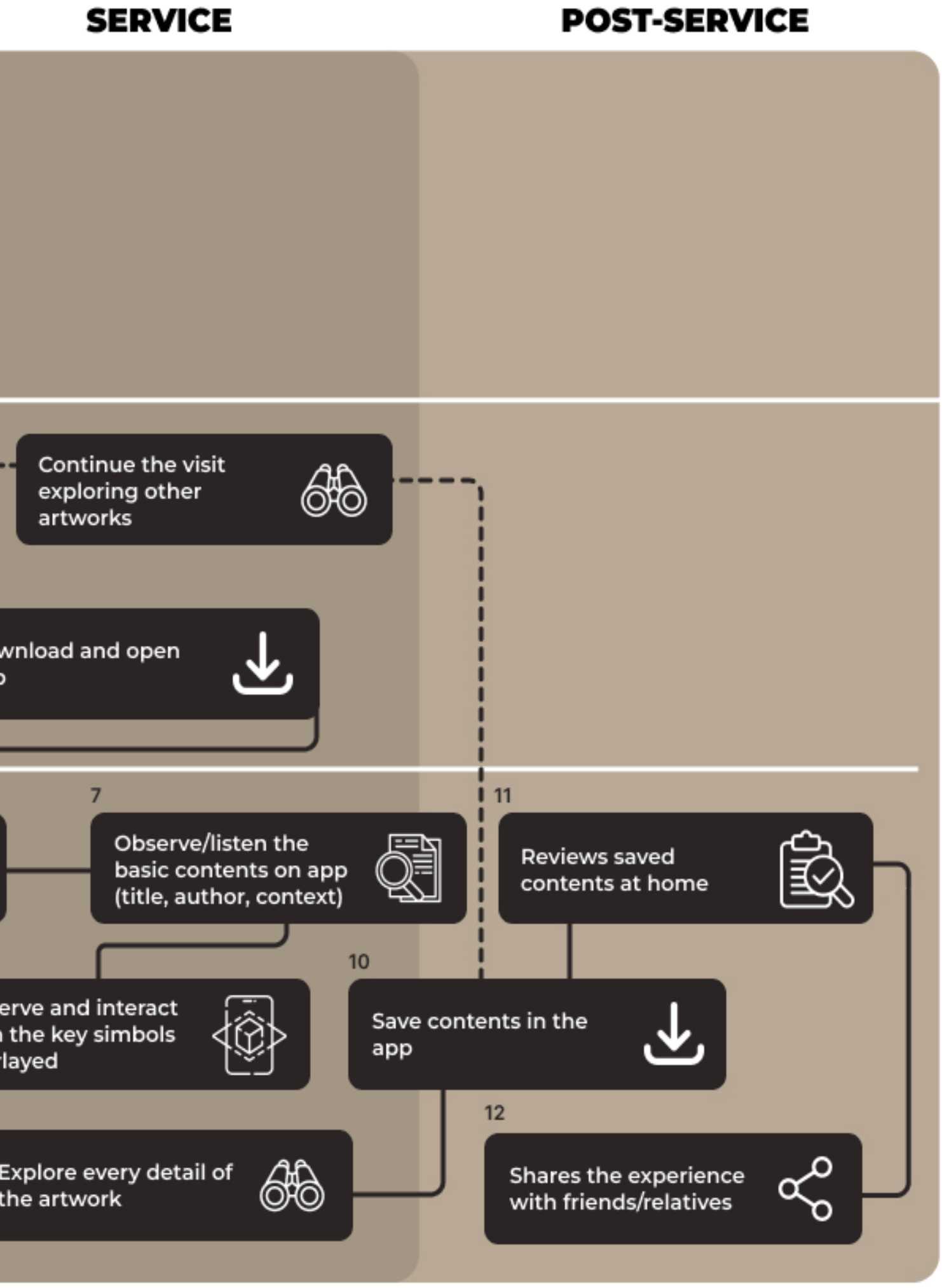

THINKS
He wonders if he is fully grasping the meaning of the works
Would like a respectful, silent and personalized experience
He fears misunderstanding what he observes
Poor information signs
Visual Opportunities Everywhere
Distracted or hasty visitors, who often ignore the artistic context
SEE
FEELS
Curiosities about unknown works of art
Silent wonder when you first enter
The distance between what he observes and what he understands
Religious language difficult to decipher
Fragmentation of experience
Lack of immediate and accessible information
Feeling of missing part of the deeper meaning
PAIN

3.4 Customer Journey Map

To analyze the user experience in detail at various moments of interaction with the service, a Customer Journey Map was developed based on Flavia's profile, identified during the research phase.

The map allows for a sequential visualization of the user's actions throughout the entire visit, highlighting key touchpoints, critical moments, and design opportunities. This tool enables us to understand how needs and expectations evolve over time and how the solution can intervene in a targeted manner, enhancing the overall experience without compromising the sacredness of the place.


TOUCH-POINTS
PRE-SERVICE
Physical and/or online marketing
Church
App
1
Discover the church online or by sign
AD
2
Search information on artworks
3
After entering the church, locate the main works of art.
4
Discover the AR app via the panel/QR code near the artwork.
5
6
Point the smartphone's camera at the fresco
8
9

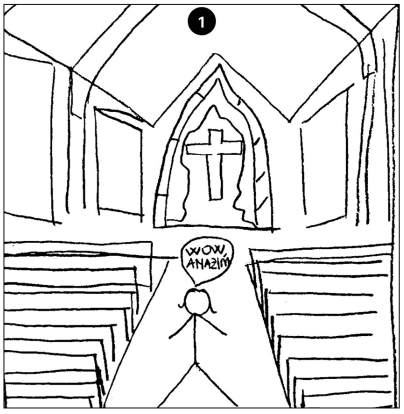

SERVICE
POST-SERVICE
Continue the visit exploring other artworks
wnload and open
7
Observe/listen the basic contents on app (title, author, context)
11
Reviews saved contents at home
erve and interact the key simbols layed
10
Save contents in the app
Explore every detail of the artwork
12
Shares the experience with friends/relatives

3.5 Storyboard and Sketch

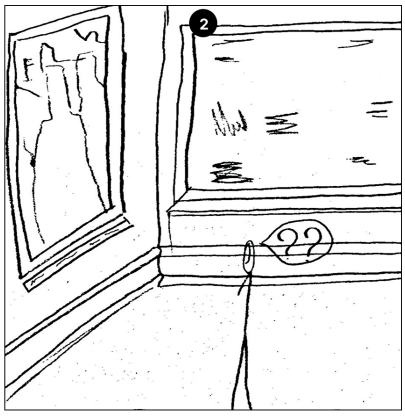
To translate research insights into concrete usage scenarios, storyboards and preliminary sketches were developed. These tools enable a narrative and immediate visualization of the primary usage scenarios of the AR application, highlighting key moments of interaction between the user, sacred space, and technology.

The storyboard recounts the user's journey step by step, highlighting needs, emotions, and context, while the sketches represent the initial visual and functional hypotheses of the interface and interactions. Together, these two techniques support the creative process, facilitate the communication of design ideas, and provide a shared basis for subsequent design development.

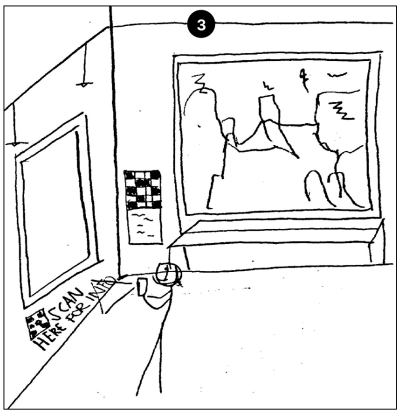
1) Flavia enters the church and is struck by the quiet and sacred beauty of the space.



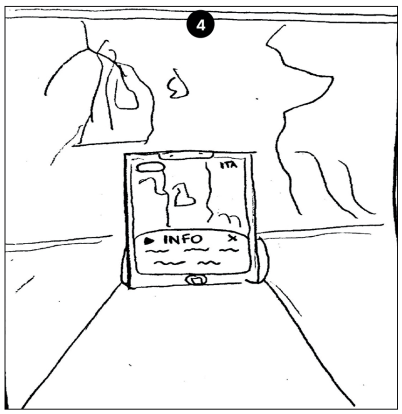
2) She stops at the Madonna dei Pellegrini but cannot fully grasp its meaning.



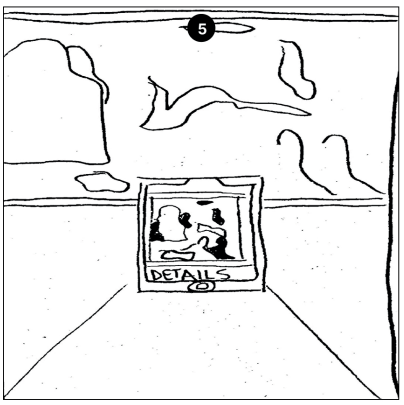
3) She notices a QR code near the artwork and decides to download the AR app on her smartphone.



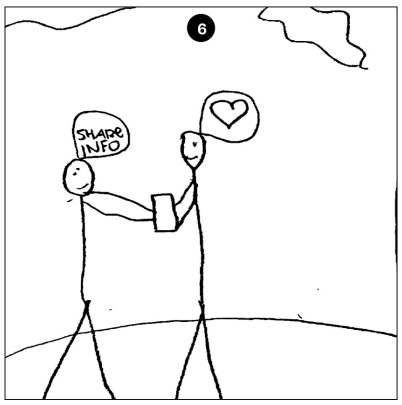
4) She points her phone at the fresco: the app displays clear text with title, author, and historical context.



5) She activates the AR content: visual reconstructions and explained symbols appear on screen.



6) After the visit, she shows her husband the saved contents, sharing her emotions and discoveries.



3.6 Visual and Interaction References

During the project's design process, it was crucial to analyze existing visual and interactive references, which offered both conceptual and functional insights. These benchmarks were considered models from which to draw inspiration for languages, interaction methods, and communication approaches. The goal was to identify solutions that have already been tested in diverse contexts to understand which strategies could be most effective in cultural mediation and the valorization of artworks through augmented reality.

3.6.1 Intelligent Cathedrals (Allal-Chérif, 2022)

The Intelligent Cathedrals project introduced the integration of AR, VR, and AI in three European cathedrals (Notre Dame, Exeter, and Seville), with the aim of improving the visitor experience without compromising the liturgical dimension. This example illustrates how digital technologies can be effectively integrated into religious contexts while maintaining a balance between sacredness and innovation. My project was inspired by The Intelligent Cathedrals work because it demonstrates that, when designed with respect, augmented reality can become a tool for cultural mediation within sacred spaces.

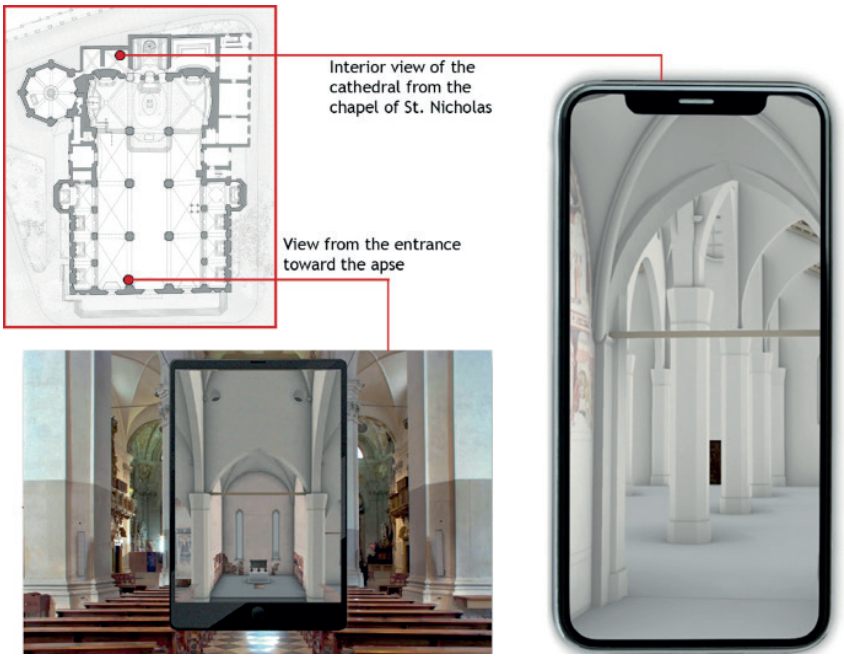


Figure 30 - Logical architecture and mock-up of the The Intelligent Cathedrals project

3.6.2 Augmenting the Invisible (Concept Design, 2019)

Augmenting the Invisible is a conceptual speculative design project that explores the role of AR as a tool for revealing what is ordinarily invisible to the naked eye. The experience is not limited to overlaying visual information, but aims to bring to light hidden meanings, forgotten histories, or invisible connections. This reference was important because it prompted me to consider AR not only as an information medium but also as a language capable of generating new interpretations and perspectives, particularly relevant in a complex context like religious practice.

Figure 31 - Exhibition of the concept design project "aumentino the invisible"

3.6.3 Smartify App

Smartify is one of the most popular museum apps globally, used in over 100 museums and cultural sites. It allows visitors to frame a work of art with their smartphone for instant access to information, descriptions, and multimedia content. The app also offers customization features, such as the ability to create personal galleries and save content for later viewing. Smartify's strength lies in its ease of use and intuitive interface, making it accessible to a wide range of audiences. For my project, it was a source of inspiration, especially in its fluid interaction management: a simple gesture like framing an image becomes a gateway to complex and layered content.

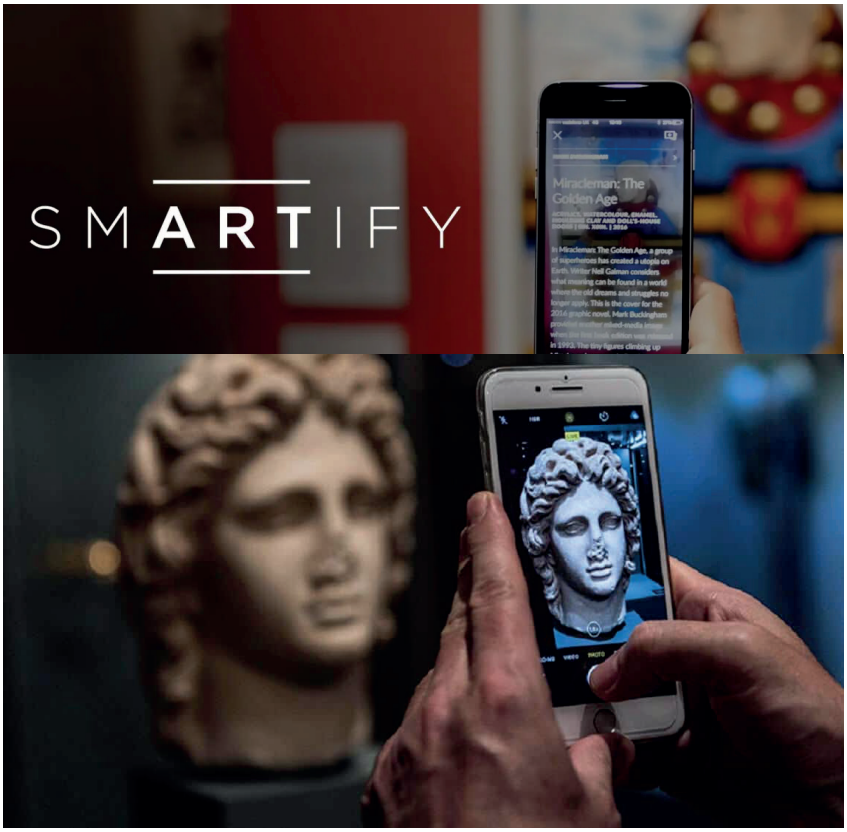


Figure 32 - Use and logo of the smartify app

4.6.4 Google Arts & Culture (AR Experiments)

Smartify is one of the most popular museum apps globally, used in over 100 museums and cultural sites. It allows visitors to frame a work of art with their smartphone for instant access to information, descriptions, and multimedia content. The app also offers customization features, such as the ability to create personal galleries and save content for later viewing. Smartify's strength lies in its ease of use and intuitive interface, making it accessible to a wide range of audiences. For my project, it was a source of inspiration, especially in its fluid interaction management: a simple gesture like framing an image becomes a gateway to complex and layered content.

Figure 33 - Mock-ups explaining the features of Google Arts & Culture

3.7 Moodboard

The moodboard gathers visual, color, and stylistic suggestions that guided the definition of the project's visual identity. The selection of references was based not only on aesthetic analysis, but also on a discussion with a priest, who provided valuable suggestions on how to convey the values of sobriety, respect, and spirituality inherent in the sacred context.

Indeed, the conversation highlighted the importance of avoiding visual excess or overly bright hues, favoring clear, elegant, and harmonious communication that complements the visitor's experience without overwhelming it. For this reason, the color palette leans toward neutral colors, the typefaces are legible and straightforward, while the selected images evoke silence, depth, and contemplation.

As a result, the moodboard thus becomes not only a stylistic guide, but also a tool for ensuring consistency between the app's design and the spiritual environment in which it is inserted.


AM·ET·APSENTI·ET·
NON·RECEPI·
ADMINISTRAVI·VT·
PENSA·ET·CVRA·
/LIBVS·M·
T·Q·TVBE
A·POTESTATE·SOLVS·

04. DESIGN

4.1 System Map

The system map was designed to clearly and concisely represent the main features of the application and the advantages they generate for the user. It highlights the paths of interaction, connecting the initial points of contact with the app's two central functions: narrative context and exploration of symbols. These functions directly respond to the requirements identified in the research phase: the need for contextual information to overcome the limitations of traditional panels and the desire for deeper involvement with symbolic and iconographic details. By mapping these interactions, the system map makes explicit the relationship between user requirements, design choices, and expected outcomes, showing how each feature contributes to a coherent ecosystem: the narrative context fosters comprehension and cultural immersion, while the symbol exploration promotes active engagement and spiritual reflection. In this way, the diagram demonstrates the alignment between research insights and the application's experiential objectives.

Context and na

The system generates a descriptive panel linked to the scanned fresco

1

- Greater understanding
- Easier accessibility

Start from

User framing
with the

- Active engagement
- Improved readability

Start from

The framed fresco shows overlays with highlighted symbols.

1

Discover the

arrative mode

2 The system offers the user a multilingual audio guide

More inclusive experience

Greater engagement

Framing

g the fresco
AR App

Differentiated in-depth analysis

Personalized experience

n Button

2 Clicking on the symbols will show iconographic details

details mode

4.2 Wireframes

Wireframes represent the first translation of design ideas into low-fidelity visual schematics. They are tools that allow us to define the application's structure and main flows without focusing on the definitive graphical aspects. In this phase, the goal was first to verify the consistency of functionality, then to organize content, and finally to anticipate how users would interact with the fresco and information layers. Wireframes, therefore, played a crucial role in mediating between ideation and design, enabling us to visualize and test the primary paths before developing the final interface. In particular, wireframes directly respond to two requirements that emerged during the research: on the one hand, the need for a clear and accessible organization of content, capable of overcoming the fragmentary nature and shallow depth of traditional tools; on the other, the need for an intuitive interaction that allows the visitor to explore the details of the work without feeling overwhelmed by technological complexity. Their function is therefore to ensure that the application translates information and perceptual needs into a coherent and usable digital experience.

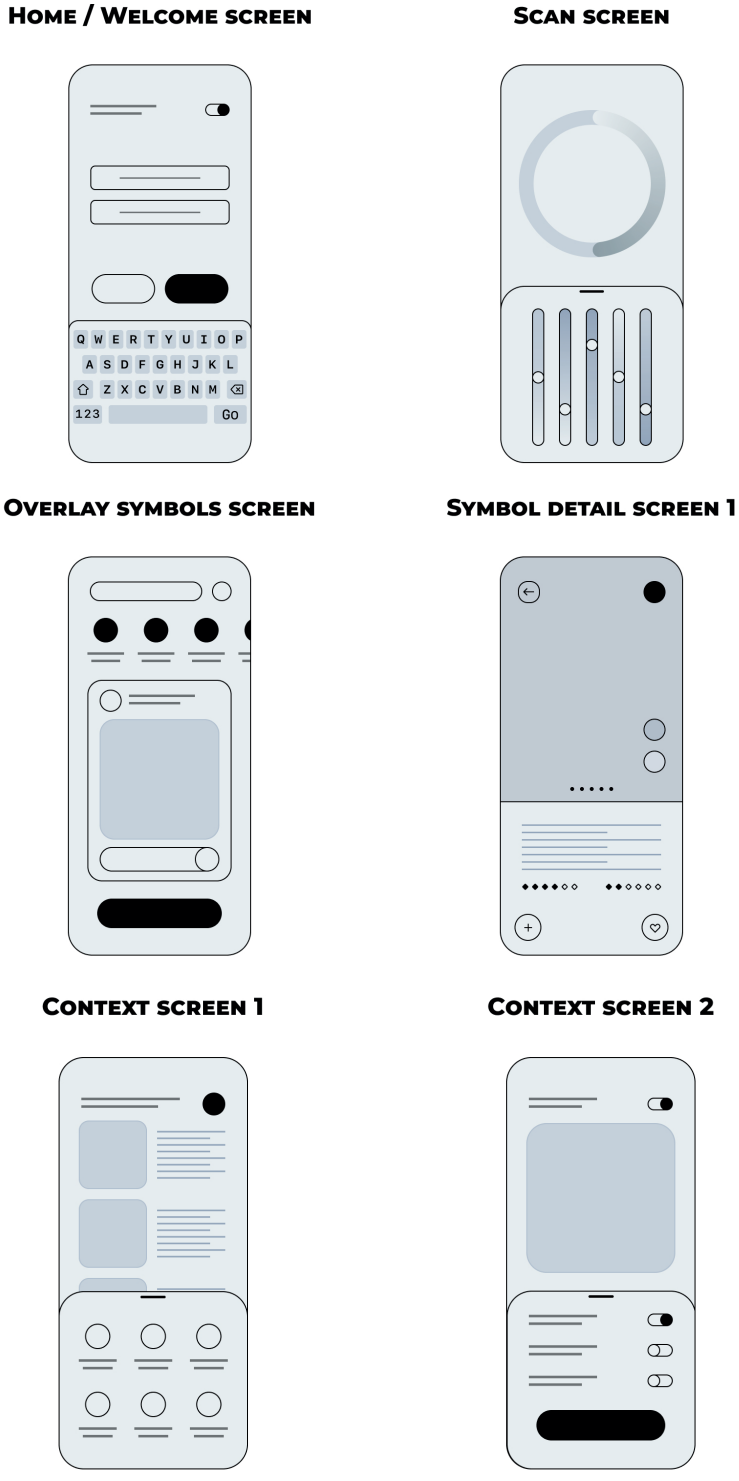


Figure 34 - Wireframs of the mobile App

4.3 Logical architecture

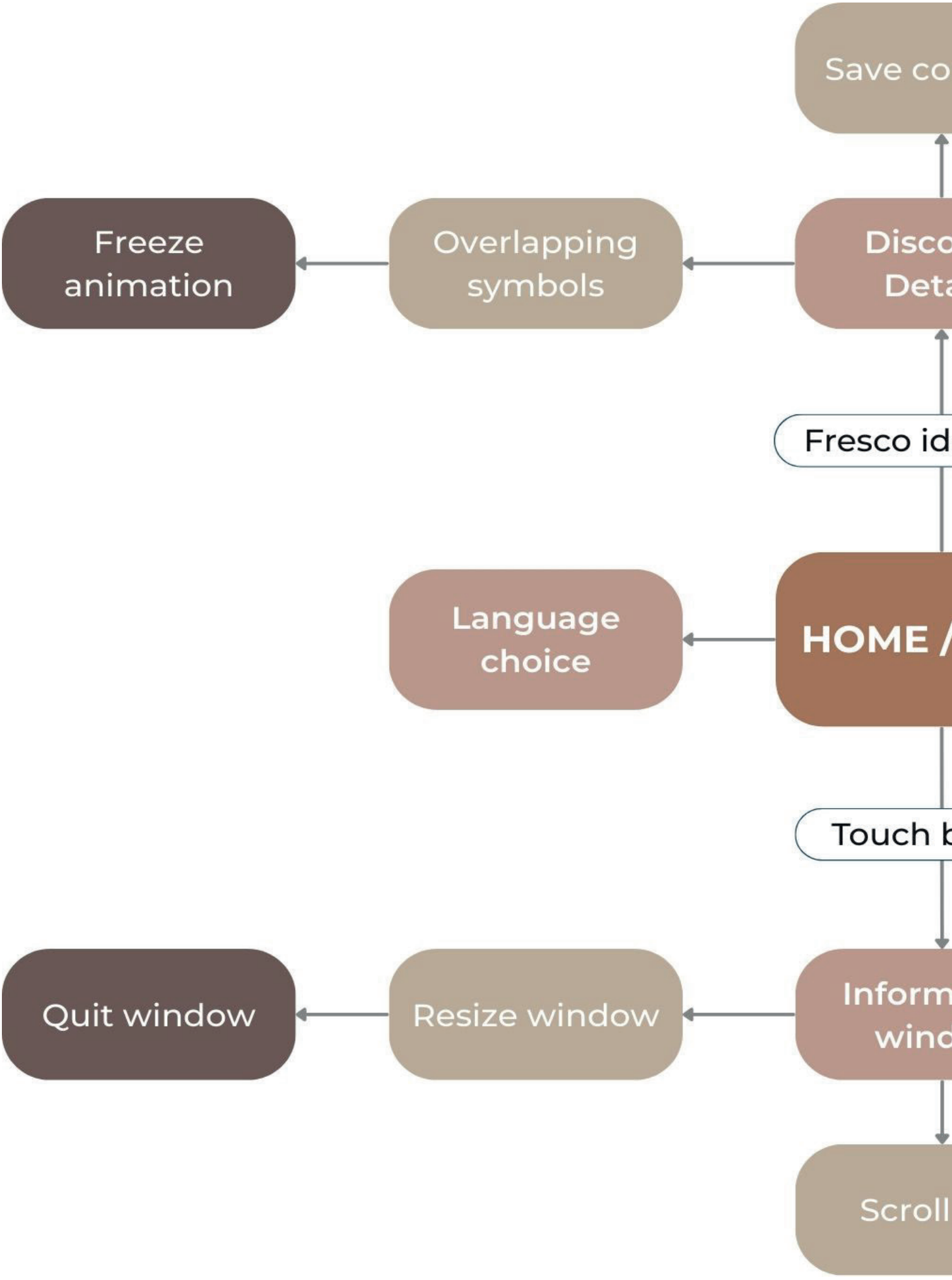
The app's logical architecture is represented through a diagram showing the main interaction paths starting from the Home/Scan screen. This logical approach ensures both clear and intuitive navigation, as well as the ability for users to customize their experience according to their interests and time.

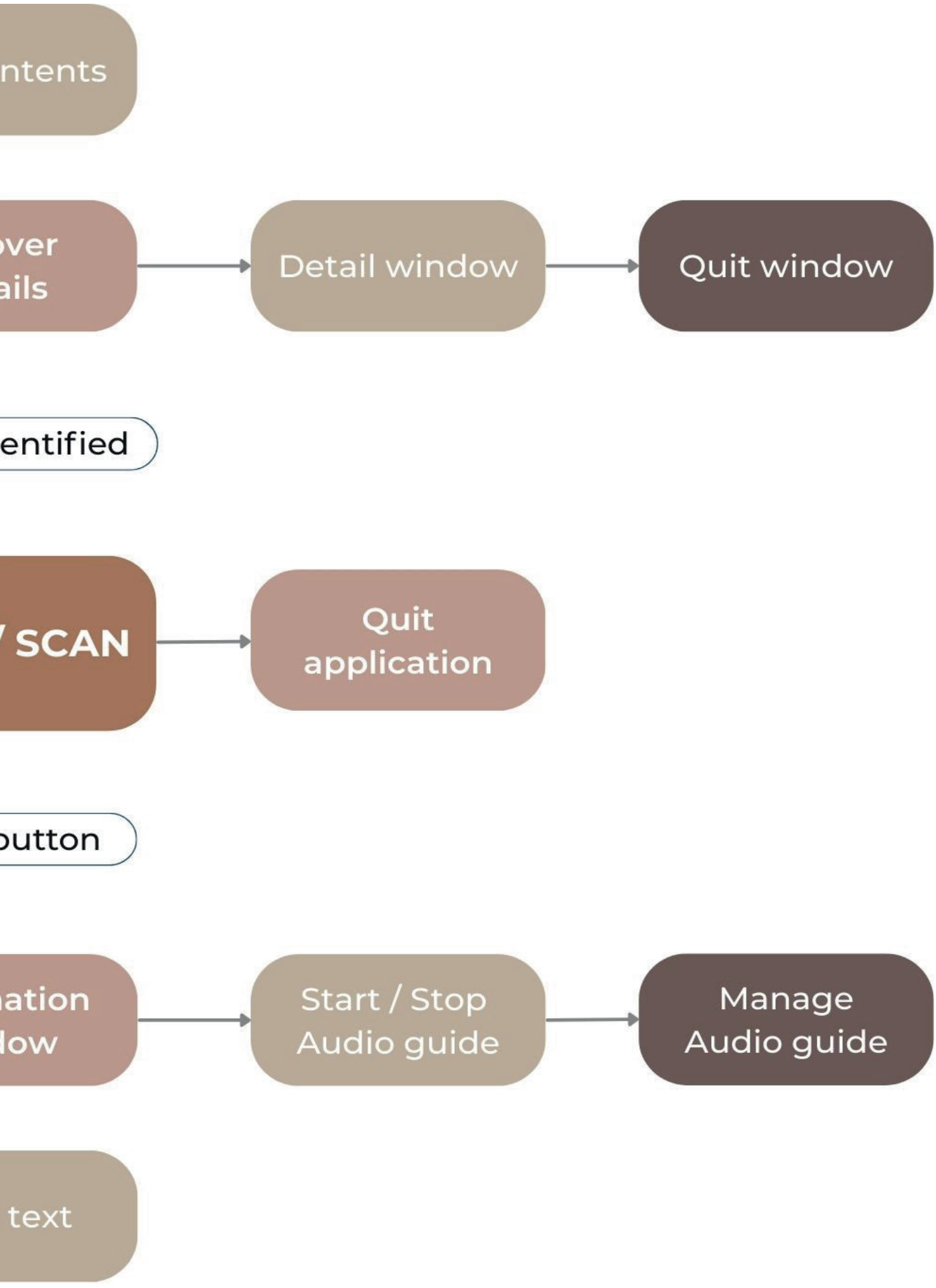
Going into detail, the first functional core concerns artwork recognition: using the device's camera, the application waits to identify the fresco and, once recognized, activates a dedicated information flow. A contextual window then appears, providing the visitor with a description of the fresco, the historical context, and additional interpretative content. This window was designed in a modular manner to allow for different modes of use: the text can be quickly scanned or explored in greater depth by scrolling vertically, and the window can be minimized to avoid obstructing direct viewing of the artwork. Moreover, the visitor can start a synchronized audio guide, especially useful in contexts where reading is less comfortable.

Alongside this initial informative feature, the app introduces a second experiential mode. Pressing a dedicated button, users can activate digital overlays directly on the fresco, highlighting significant symbols or figures. Each detail becomes interactive: tapping it opens a detailed panel illustrating the symbolic and theological significance of the selected element.

Both features are integrated with a multilingual system, allowing users to select the language in which they wish to view both text and audio content at any time.

These architectural choices directly address the requirements identified in the research phase: the need for accessible and multilayered information, the demand for multilingual support expressed by international visitors, and the request for more engaging tools to interpret symbolic details. By structuring the app around two complementary modes—contextual descriptions and interactive overlays—the design ensures that informational depth and experiential immersion are not mutually exclusive but integrated, thus overcoming the limitations of traditional mediation devices.


Save co
Freeze animation
Overlapping symbols
Disco Deta
Fresco id
Language choice
HOME /
Touch b
Quit window
Resize window
Inform windo
Scroll


ntents
over
ails
Detail window
Quit window
entified
/ SCAN
Quit
application
button
nation
dow
Start / Stop
Audio guide
Manage
Audio guide
text

4.4 Design Rationale

The following outline summarizes the principles that guided the design process for the augmented reality application. These principles were not developed in abstract terms, but are the result of in-depth reflection developed in two complementary directions: on the one hand, primary research, which highlighted the needs, difficulties, and expectations of visitors to Rome's less frequented churches; on the other, a conversation with a priest from the Church of Sant'Agostino, which provided a deeper understanding of religious sensibilities, the value of silence, and the necessary respect in sacred spaces.

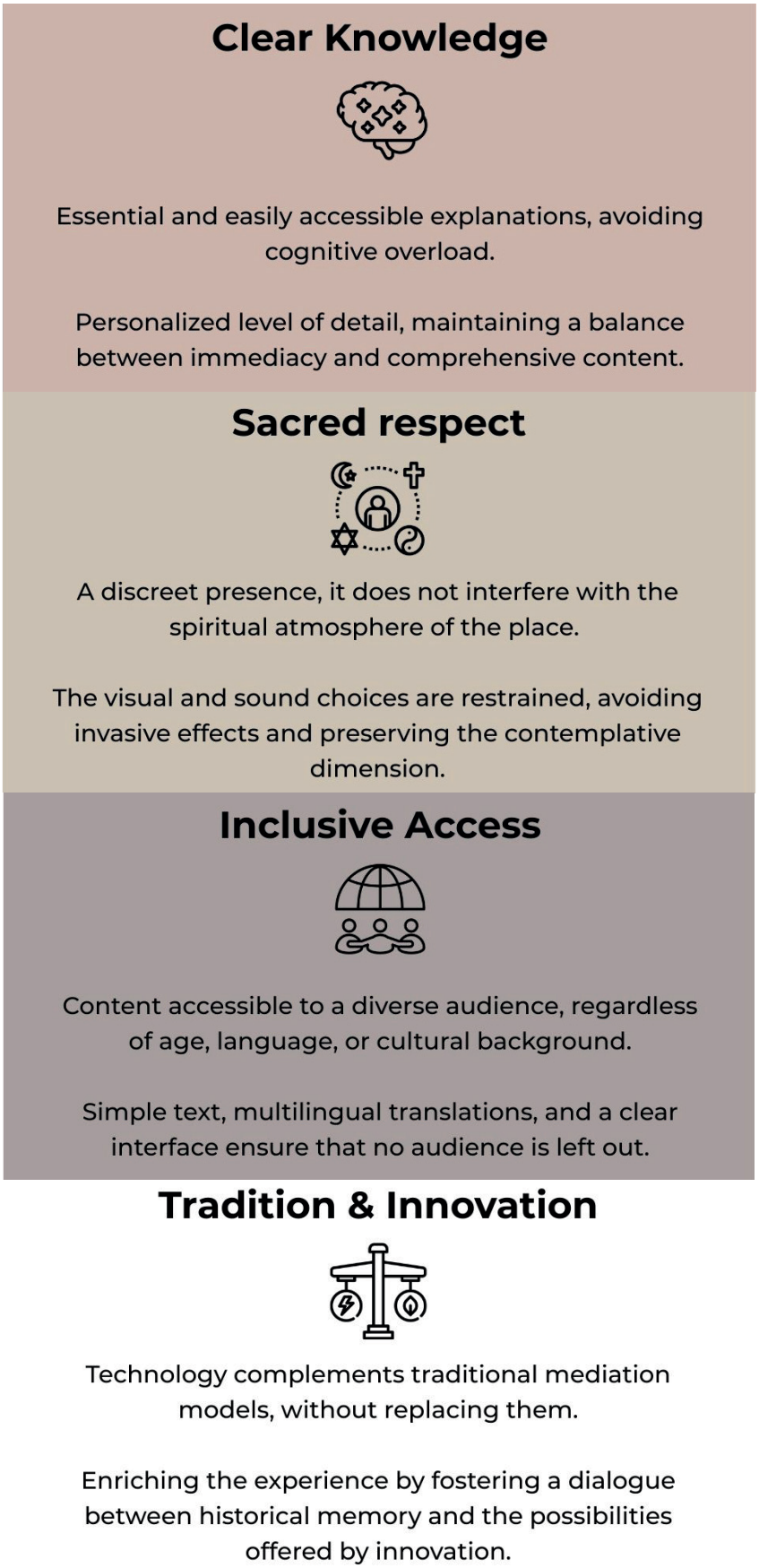


Figure 35- Summarize of the principles that guided the design process

These principles form the value and design framework within which the entire user experience was developed, ensuring that the application meets not only technological innovation criteria but also respect, accessibility, and cultural significance. In particular, they directly respond to the requirements identified in the earlier phases of the research: the need for multilingual and accessible content, the request for deeper contextual information beyond basic panels, and the importance of creating an interaction model that does not disrupt but rather supports the liturgical atmosphere. By translating these requirements into guiding principles, the design process guaranteed that every functional and aesthetic choice remained aligned with both visitor expectations and the sacred dimension of the context.

4.5 UI Design

The user interface represents the direct point of contact between the application and visitors. After defining the project's guiding principles, attention was focused on visually translating these values into concrete design choices. This section illustrates the decisions related to colors, typography, layout, and visual elements, highlighting how each feature contributes to ensuring a balance between information clarity, usability, and cultural consistency.

In particular, the interface design responds to the requirements identified in the research phase: the need for clear and legible content for an international audience, addressed through high-contrast typography and multilingual layouts; the demand for intuitive navigation, reflected in a simplified and consistent layout; and the necessity of cultural sensitivity, expressed through a restrained color palette and visual elements that respect the sacred atmosphere of the churches. In this way, aesthetic decisions are not merely stylistic, but functional responses to user needs and contextual constraints.

Color Palette

The color palette is deliberately understated and neutral, with hues that evoke the colors of stone and frescoes. This choice is motivated by the need to respect the sacred nature of the site, avoiding overly bright or invasive colors that could disrupt the church's visual harmony. At the same time, contrasts are carefully calibrated to ensure the text is legible and the interactive buttons are immediately recognizable.

Typography

For the main texts, a clear and linear sans-serif font was chosen, easily readable even on small screens. On the other hand, the in-depth sections or quotes use a serif font that evokes elegance and tradition, creating a balance between modernity and historical memory. This combination reflects a desire to balance technological innovation with cultural continuity.

Layout

The interface is organized into discrete overlays that appear directly over the artwork in focus without obscuring it. The buttons are few, essential, and intuitively positioned to minimize distraction during the experience. The user can seamlessly transition from reading text to discovering iconographic symbols, always maintaining a sense of continuity with the actual fresco. Furthermore, the balanced use of soft shadows and blurs helps visually separate the layers, clarifying the hierarchy of information. The balanced management of empty spaces reduces the risk of visual overload and encourages a slower, more meditative interaction.

Patterns and Motifs

The overall style is minimalist and respectful of the sacred environment. Spectacular effects are completely avoided, favoring light animations and discreet information overlays. The app is designed for a diverse audience, featuring concise, clear text and universal icons that ensure accessibility across various cultural backgrounds. Particular attention was paid to the icons, which were designed in a linear and essential style to be immediately recognizable and unobtrusive, thereby transcending any linguistic and cultural barriers.

Color Palette

Lorem ipsum
Stone Gray
A8A39D

Stone Gray is an excellent UI primary soothing nature, providing a pleasant muted tone reduces visual fatigue.

Warm Beige
D8C7A3

Warm Beige is a welcoming and neutra ancient walls and frescoes. Its warmth c harmony, making content more approac

Deep Brown
5A4634

Deep Brown conveys solidity and depth elements typical of sacred spaces. It readability while maintaining an atmosp

Soft White
F5F5F5

Soft White ensures clarity and purity, en icons. Its brightness balances darker to and contemplative quality.

Typography

Montserrat — ABCDEFGHIJKLMNOPQRSTUVWXYZabcdef

Modern Sans - Serif — **ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefg**

Layout

color due to its calming and
user experience. Its soft and

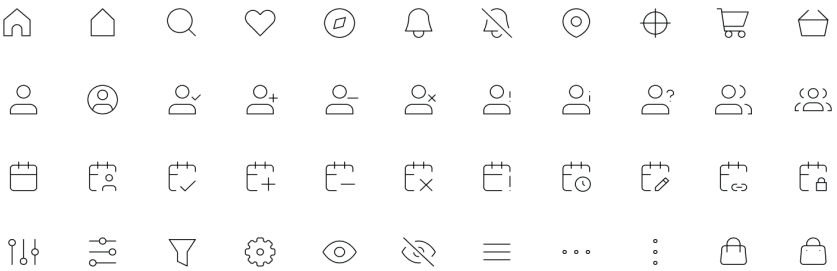
l shade that evokes the tones of
creates a sense of familiarity and
chable.

n, recalling the wood and stone
t provides strong contrast for
here of seriousness and respect.

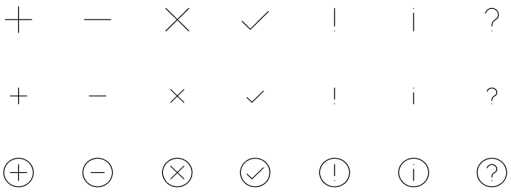
hancing the legibility of text and
nes, giving the interface a clean

fghijklmnopqrstuvwyz0123456789
ghijklmnopqrstuvwyz0123456789

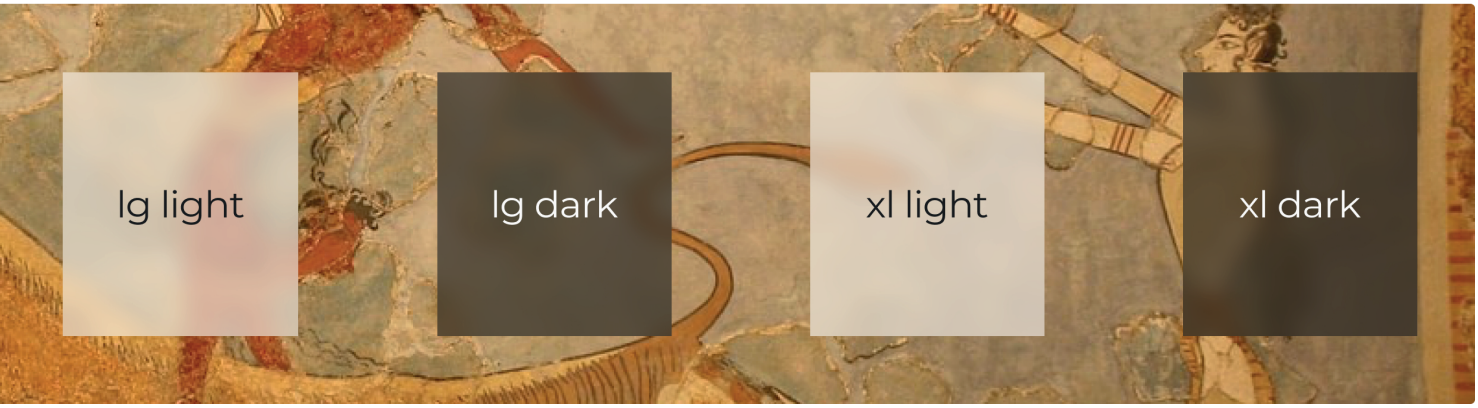
Main interface icons



Action Icons



Media icons



05. DEVELOP

5.1 Application architecture

5.1.1 System structure

The application was developed with Unity 2022.3 LTS, a tool that represents the established standard for building Augmented Reality applications on mobile devices. The choice of these platforms met two main requirements: first, to ensure stable and up-to-date support for AR image recognition and interaction management features; second, to adopt a development environment that fosters the project's modularity and scalability.

Architecturally, the application adheres to the Entity-Component-System (ECS) model, a paradigm that facilitates the clear separation of data, behaviors, and execution logic. In this approach, each application element, such as an information window, is treated as an entity. Entities do not directly possess complex logic, but are enriched by components that define specific properties, such as, in this case, multilingual text or overlay images. Finally, the systems manage the dynamic behavior of entities by applying standard rules to sets of components. For example, the recognition system triggers the appearance of the information window when the fresco is identified. At the same time, the interaction system manages the interface's response to the user's touches on the overlapping symbols.

This architecture offers numerous advantages over more traditional models, particularly in applications developed in Unity. First, it ensures clarity and order during development, as each function is isolated in a dedicated component and can be modified without affecting the others. Second, it allows for high flexibility, as the contents are organized in a local configuration file that serves as an internal database. This means that updates and modifications to the cultural materials can be made without modifying the source code, making maintenance simpler and more sustainable. Ultimately, the ECS paradigm enables future scalability. If, at a later date, the application were to be extended to a system with a remote back-end or to integrate new features, the modular architecture would allow for this without compromising the existing framework.

In this sense, although conceived as a standalone application, the proposed solution recalls the principles of distributed architectures, adopting an organization that favors the separation of responsibilities, code reusability, and the ability to adapt to more complex content and interaction management scenarios.

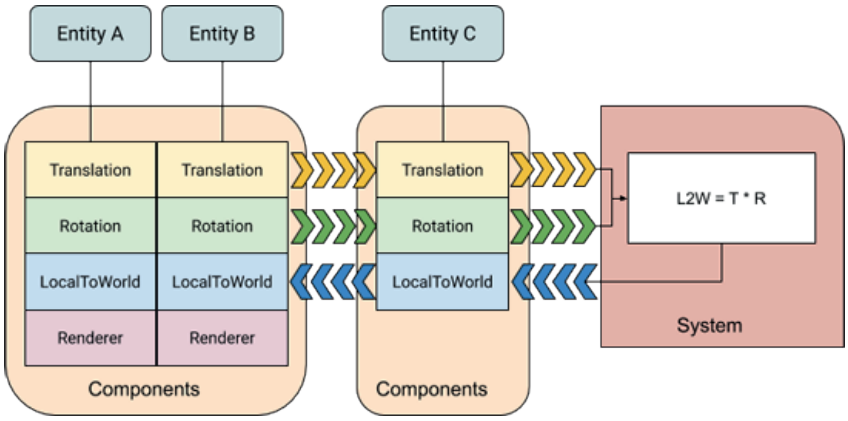


Figure 36 - Entity-Compenent-Sytem model

5.1.2 AR recognition module

The recognition module is the core of the application architecture, enabling visual analysis of the fresco. In order to havethis function, Vuforia Engine 10.17 was used, one of the leading software platforms for developing Augmented Reality applications on mobile devices. Vuforia employs a markerless computer vision approach, enabling the recognition of complex visual elements through real-time comparison between images captured by the camera and a pre-loaded dataset of visual targets.

In this specific case, the selected frescoes are previously digitized and processed to extract distinctive characteristics, called "feature points." This data is entered into the application's visual database, which serves as the reference for recognition. Once the user frames the artwork with their device's camera, Vuforia matches the features acquired in real time with those recorded in the dataset. Once a certain level of reliability is reached, the system recognizes the fresco and automatically begins loading the associated content.

This process is not limited to identification alone, but also serves as a trigger for activating the AR experience. It assumes a pivotal role in the experience, as it allows for a precise connection between digital content and the physical object, maintaining alignment between the real work and the augmented information.

The use of this technology ensures operational robustness even in less-than-optimal environmental conditions, such as reduced lighting or the presence of visitors. Moreover, it allows for perceptual authenticity to be preserved. In other words, the work remains the fulcrum of the experience, and the digital content is inserted as an additional layer of information, not a replacement. This characteristic is particularly relevant in the context of sacred places, where technology must not prevail over the artistic and spiritual dimension, but rather serve it.

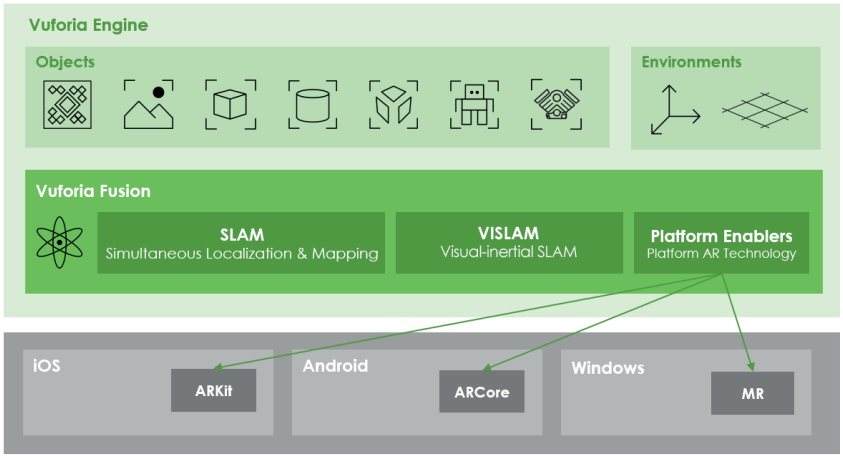


Figure 37 - Vuforia Engine 3ystem Diagram

5.1.3 AR Multimedia content managment

Cultural materials—descriptive texts, multilingual translations, audio tracks, and overlay images—are not rigidly embedded within the source code, but rather organized in a local configuration file. This approach allows the application to remain standalone, eliminating the need for internet connectivity in situations where network availability is unreliable, such as in ecclesiastical environments. From a technical perspective, the content is structured hierarchically to facilitate organization and subsequent retrieval. Specifically, each fresco registered in the system is identified by a unique code, which is associated with: a set of descriptive texts, translations, an audio track for each language, and a set of visual overlays.

5.1.4 Security and data compliance

A delicate aspect of app development concerns data management and respect for user privacy. The application is designed as a completely offline system, requiring neither the collection nor transmission of personal information to external servers. This approach ensures that there are no risks associated with the protection of sensitive data.

5.2 Technical specifications

To ensure a stable and seamless user experience, the application was designed with specific technological requirements, both in terms of software and hardware. From a software perspective, the application is compatible with Android 9.0 or higher and iOS 13 or higher operating systems, which currently represent the reference standards for most mobile devices. From a hardware perspective, the app requires devices with:

- Rear camera with a minimum resolution of 12 MP and autofocus support;

- Minimum quad-core multicore processor with 2.0 GHz or higher;

- GPU compatible with OpenGL ES 3.0 or Metal, to ensure smooth real-time graphics processing;

- Minimum 4 GB of RAM, required to manage the recognition engine, graphics rendering, and multimedia content loading;

- At least 500 MB of free storage space, to accommodate visual datasets;

Regarding multimedia content management, the materials were optimized to achieve a balance between visual quality and the overall lightweight nature of the application. Overlay images were saved in compressed PNG format. Furthermore, audio tracks were encoded in AAC at 128 kbps, a choice that maintains a good level of clarity while reducing the impact on device memory. Finally, multilingual texts are organized within JSON files, structured in a way similar to a database.

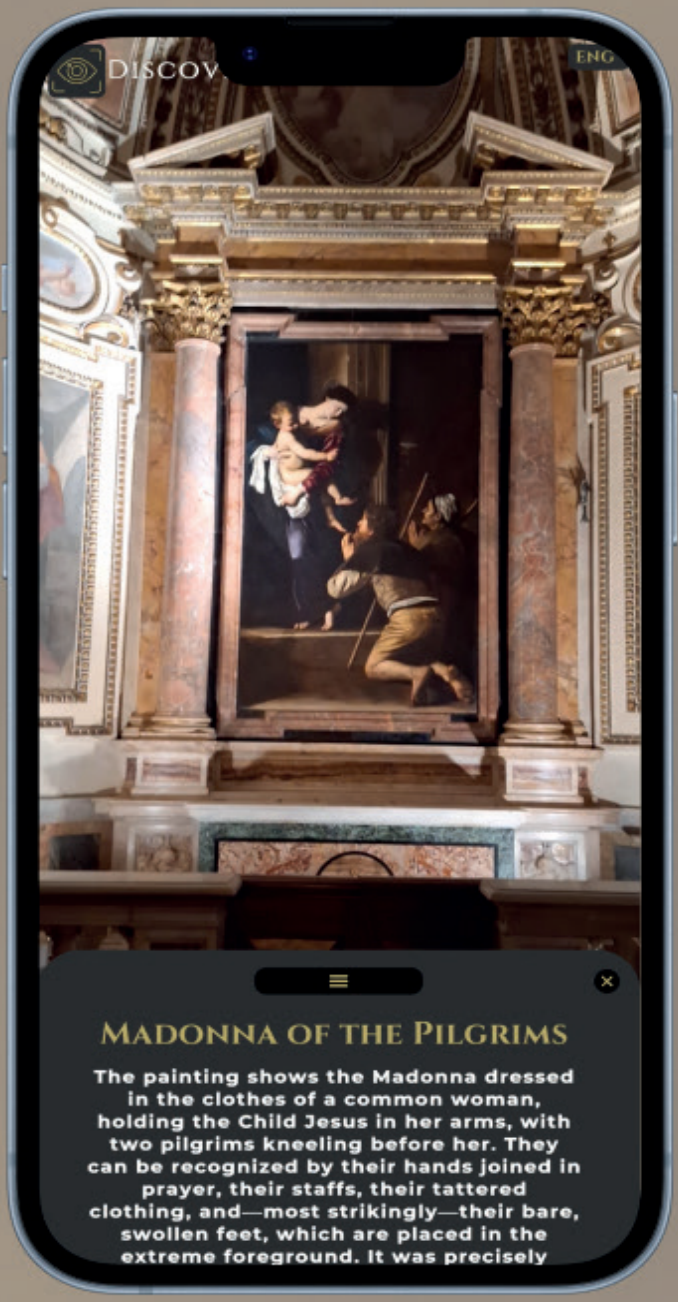
Finally, the application was tested on a Samsung Galaxy A54 smartphone, representing a range of mid- and high-end devices, to ensure operational robustness and portability. The tests verified performance stability, visual recognition accuracy, and correct content display under the varying lighting conditions typical of ecclesiastical environments.

06. InChiesa
Final outcome

App Logo

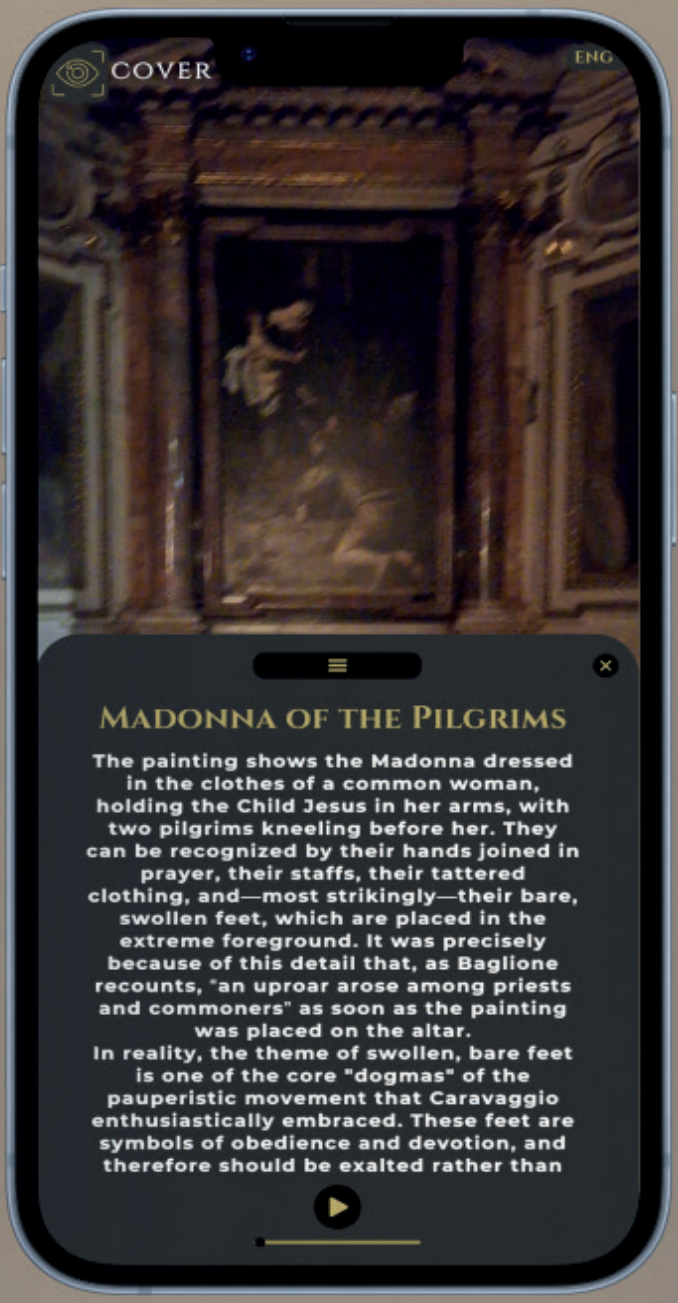
Developed with Unity

Framing of the fresco



Information Panel Mo

Audio Guide Mode



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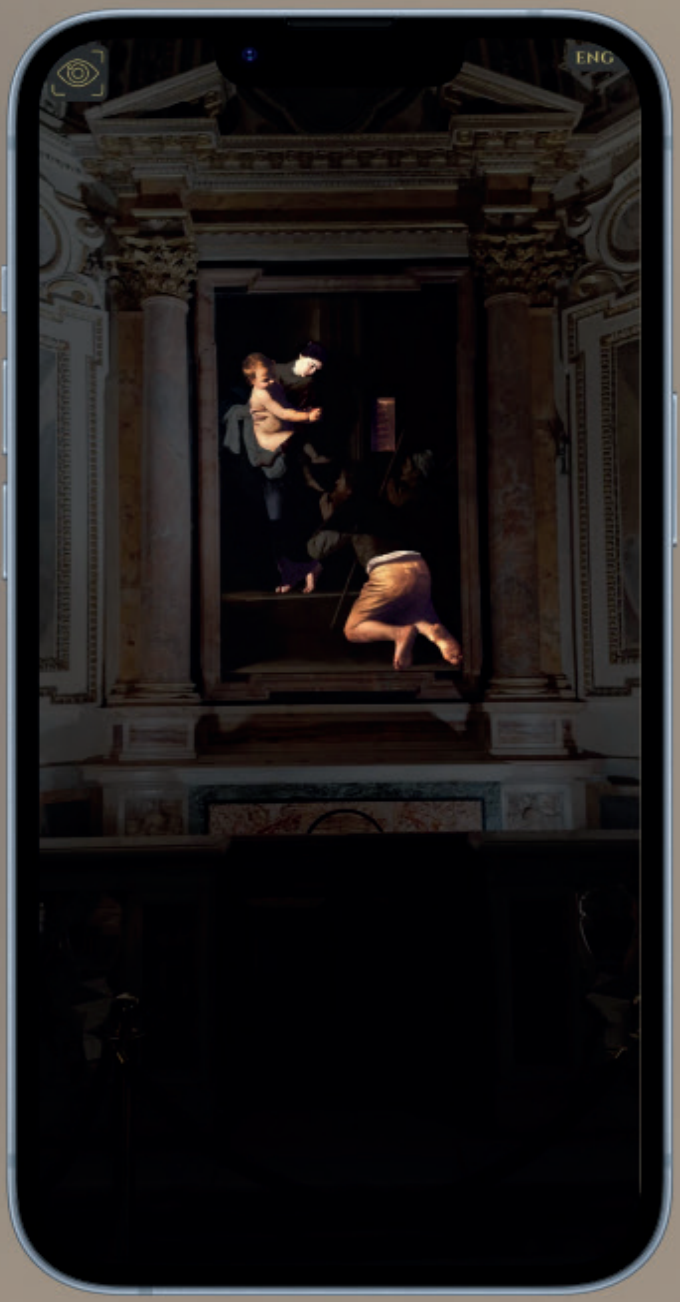
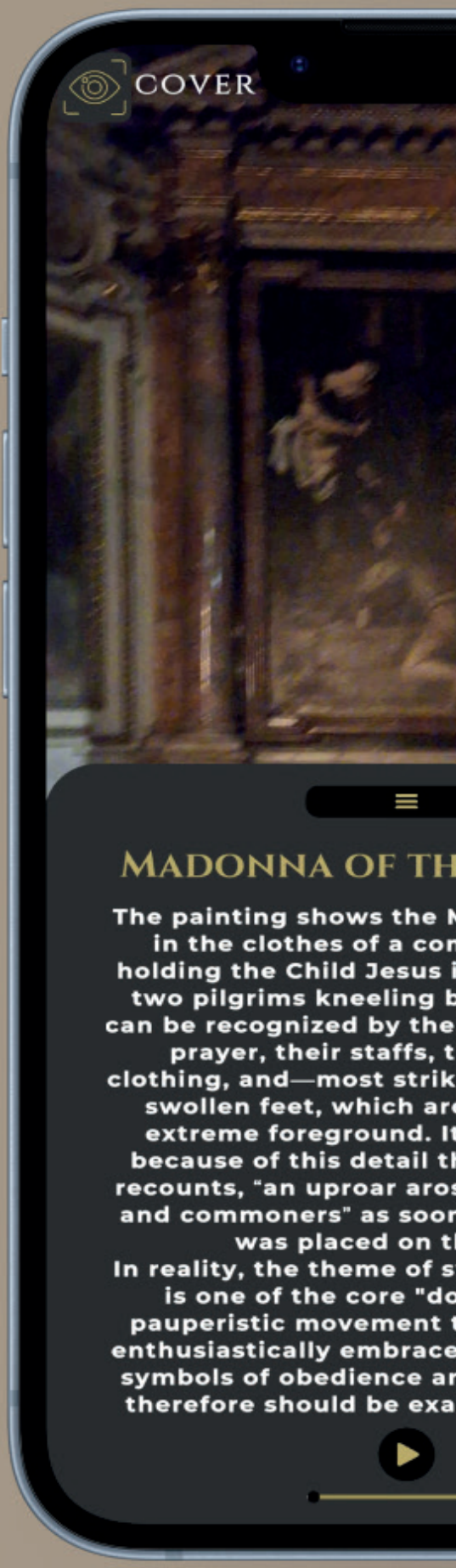
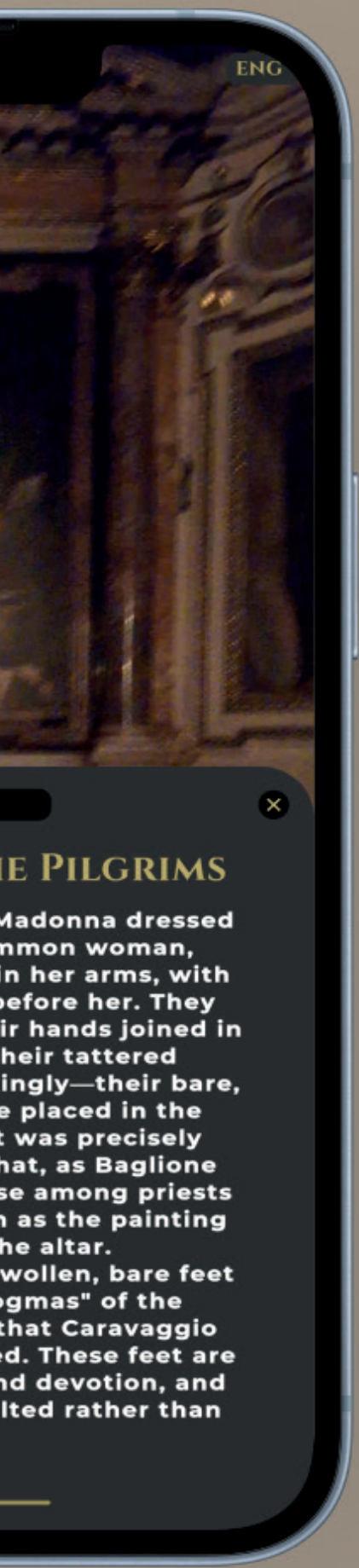


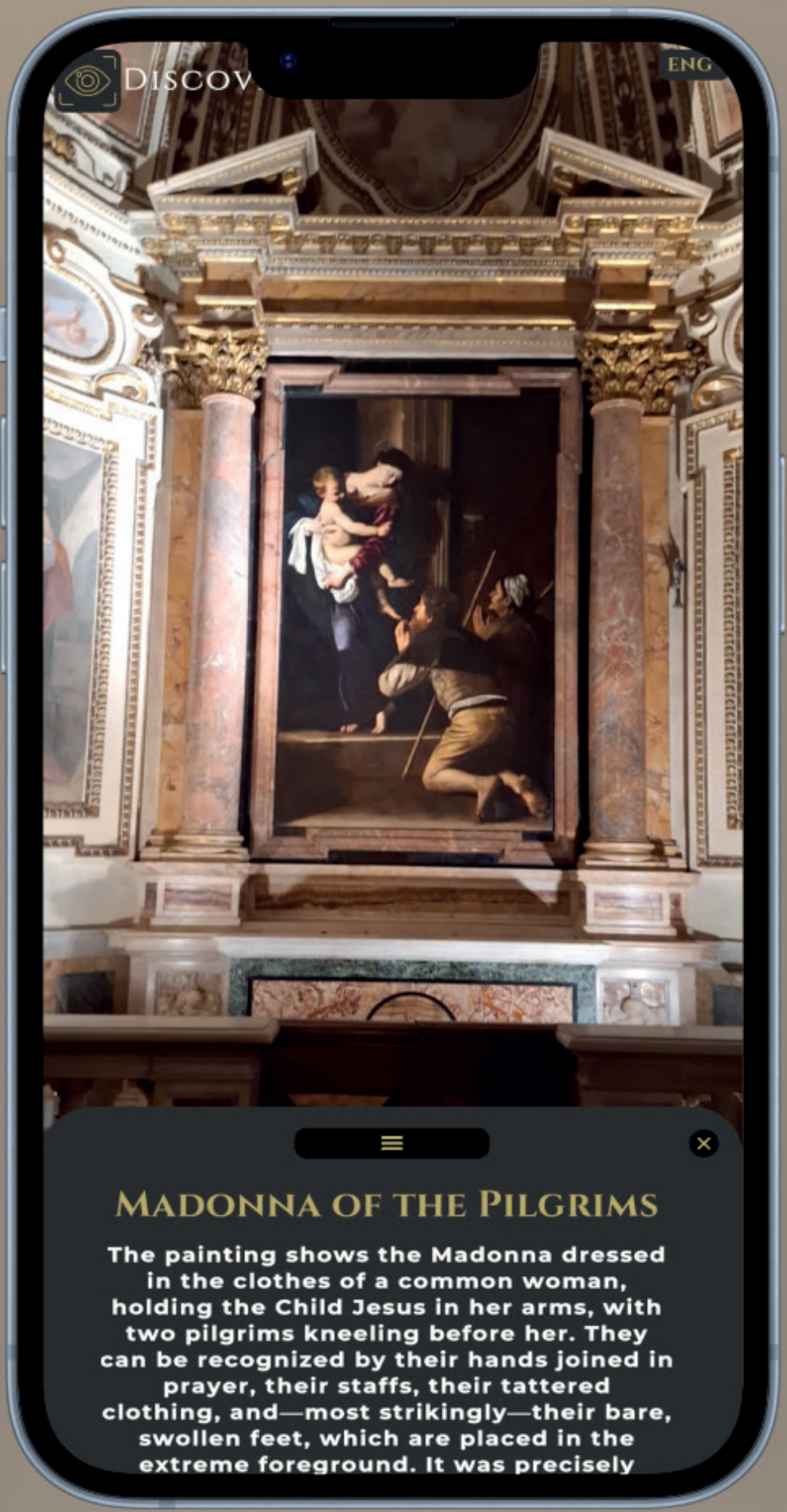
Discover Details Mode

Information Panel Mode

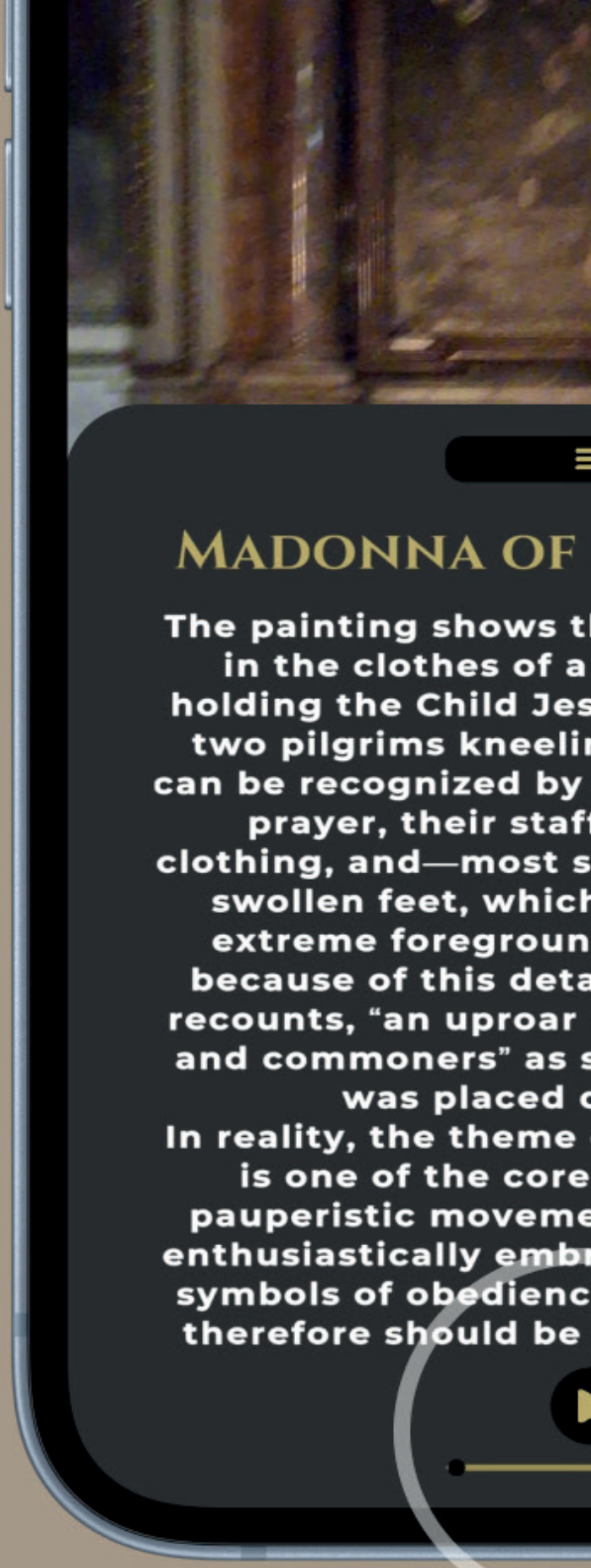
This mode is the first one presented during the application flow; it appears as soon as the app recognizes a fresco. It provides the user with historical and artistic information about the fresco.



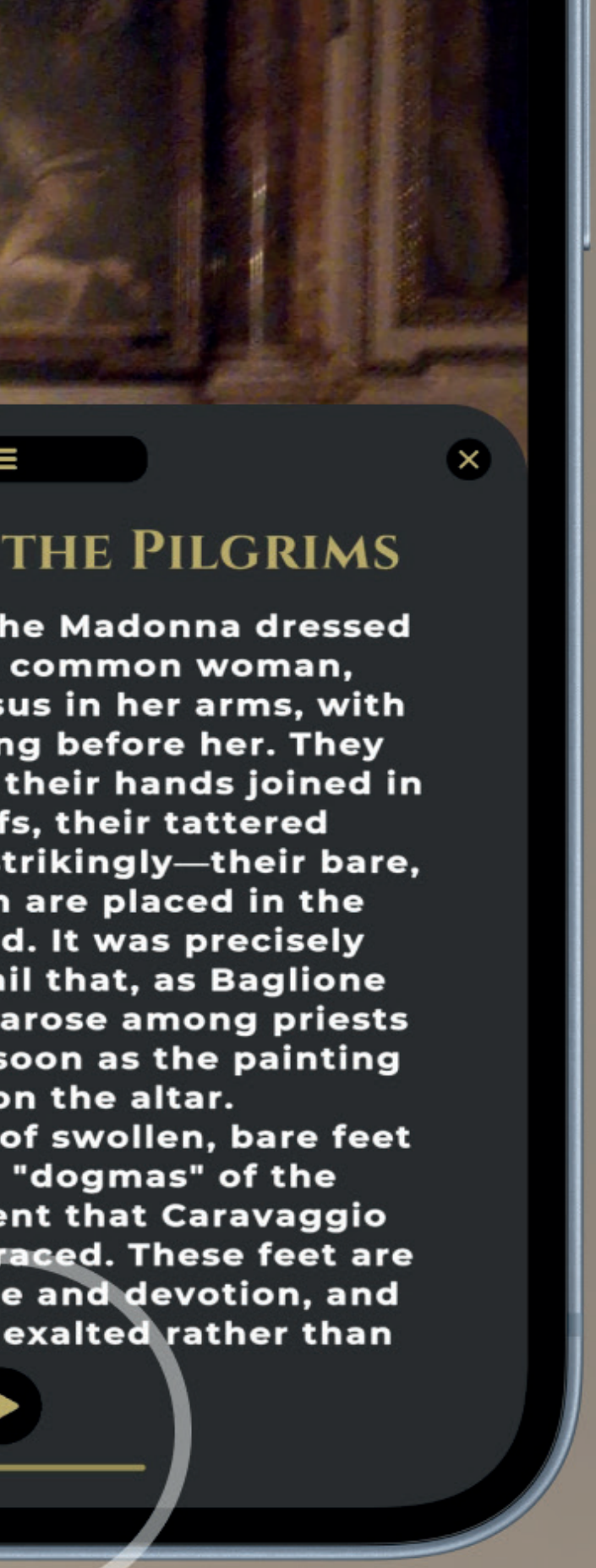

ENG
E PILGRIMS
Madonna dressed
mmon woman,
in her arms, with
before her. They
ir hands joined in
heir tattered
ingly—their bare,
e placed in the
t was precisely
hat, as Baglione
se among priests
n as the painting
he altar.
wollen, bare feet
gmas" of the
that Caravaggio
ed. These feet are
nd devotion, and
lted rather than


DISCOV
ENG
MADONNA OF THE PILGRIMS
The painting shows the Madonna dressed in the clothes of a common woman, holding the Child Jesus in her arms, with two pilgrims kneeling before her. They can be recognized by their hands joined in prayer, their staffs, their tattered clothing, and—most strikingly—their bare, swollen feet, which are placed in the extreme foreground. It was precisely

The dynamic Play/Stop button allows you to manage text playback independently, allowing the listener to focus on a detail. The audio changes based on the selected language.

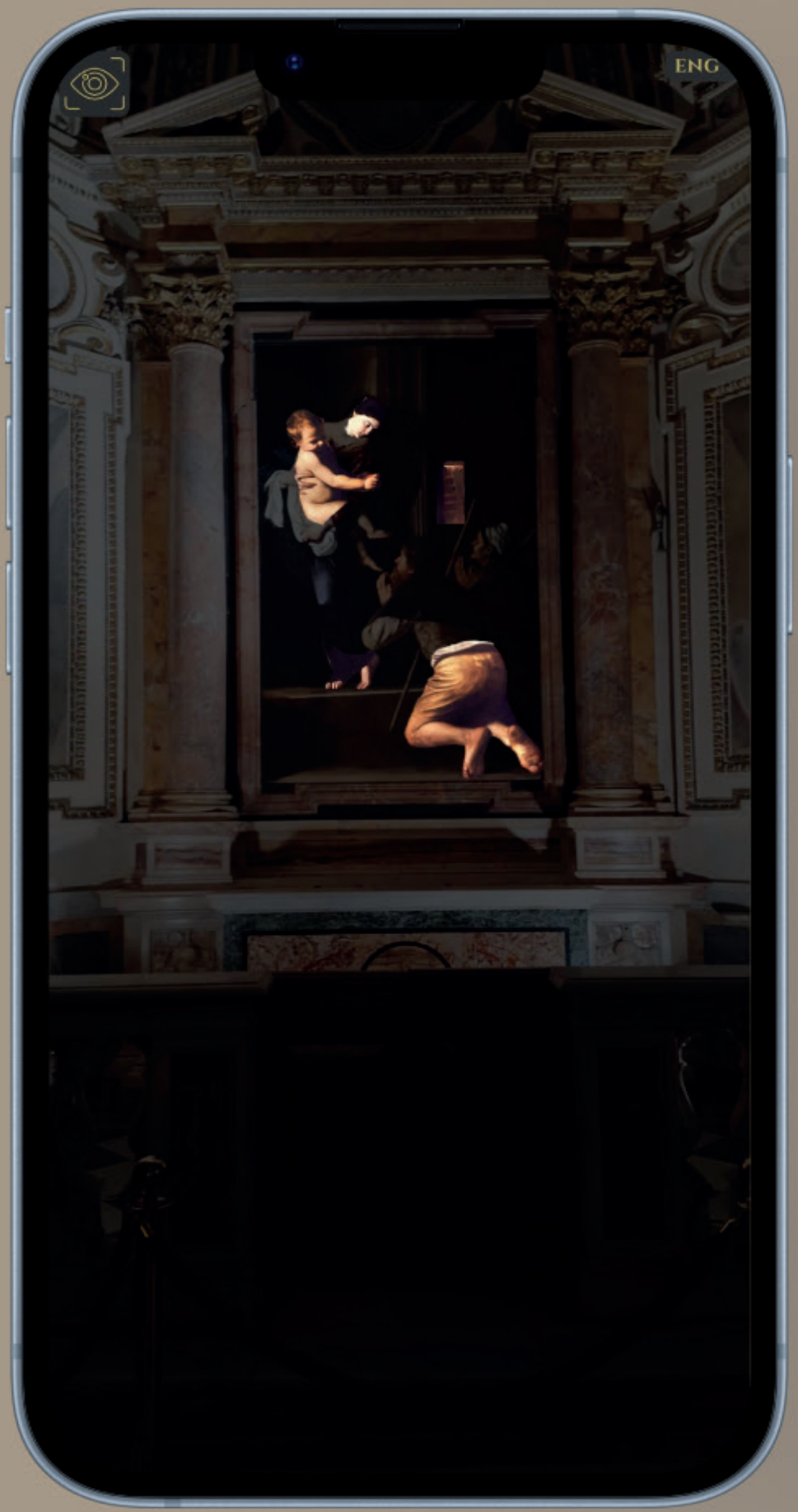


Audio Guid



The bar allows users to rewind the audio to any position

le Manager


ENG


Feet of
Symbol of h
swollen and
penite

Discover Details Mode

The mode can be activated with a button. It allows users to display details that aren't visible to the naked eye due to the distance of the fresco. Additionally, the details can be touched to explore their meaning.

“Barefoot Virgin” Detail

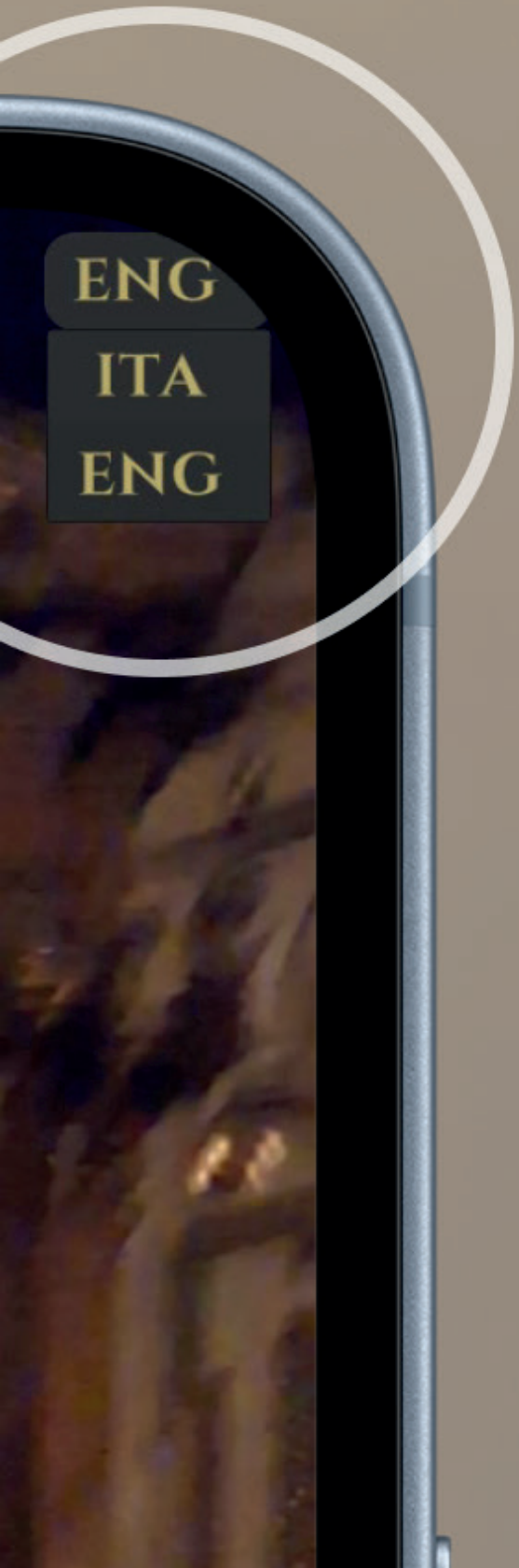
“Madonna’s Face” Detail

“Jesus Child” Detail

“Pilgrims’ Feet” Detail


ILS

Drop-down menu to change language

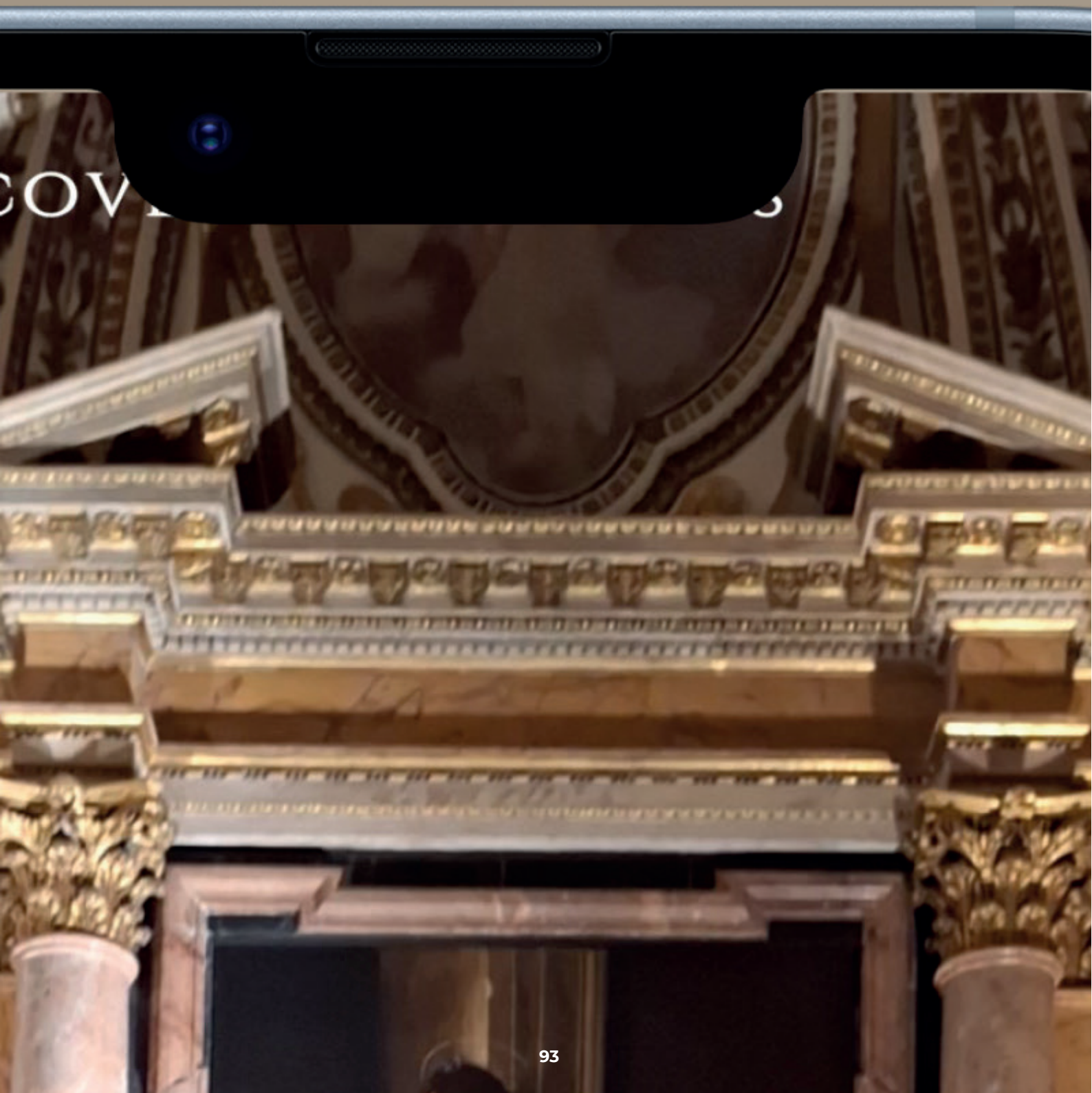


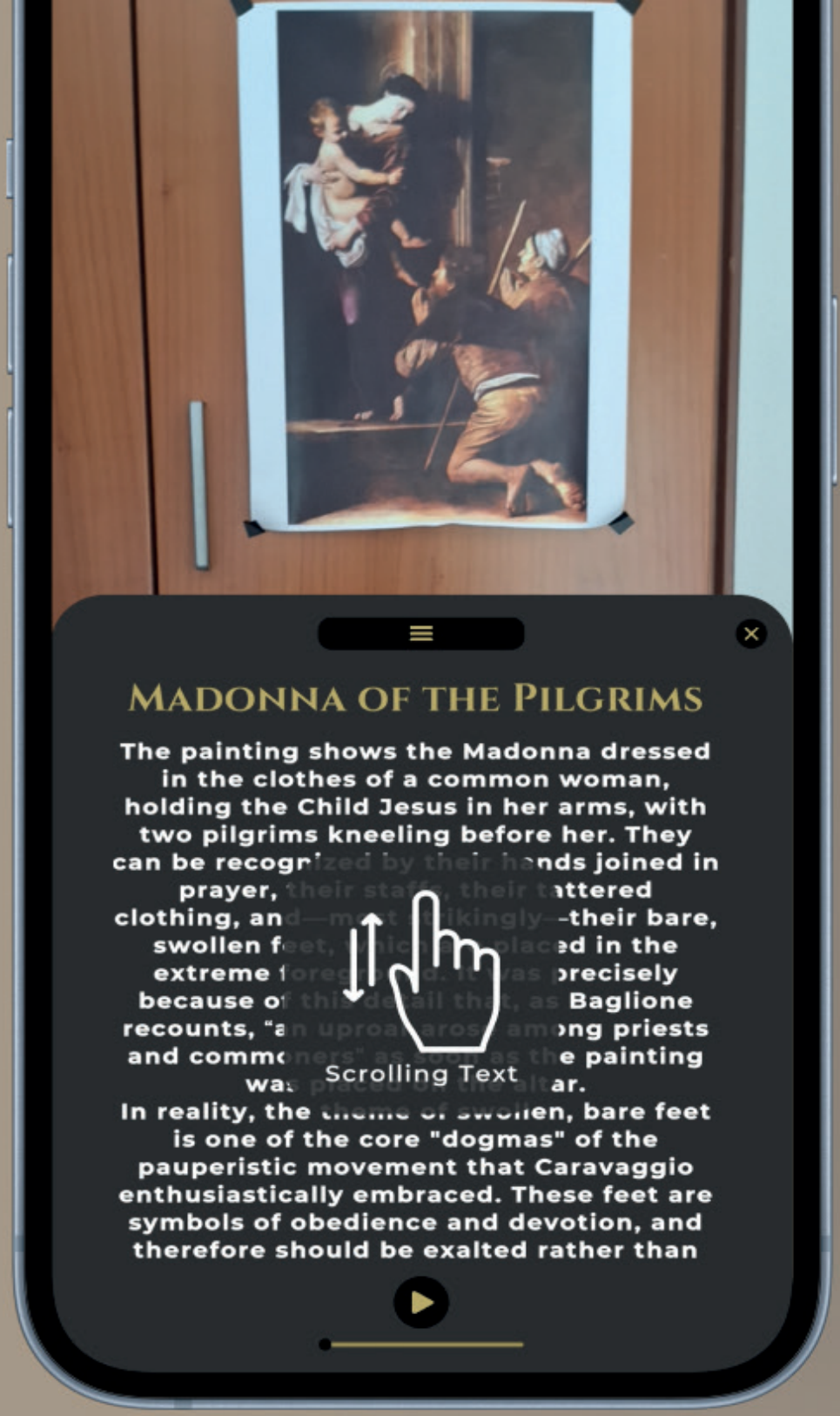
The drop down button has been preferred, making the application scalable in terms of languages

Button to switch to "discover details" m

A scrolling text has been added to highlight the possibility of pressing the button to switch to "discover details" mode and vice versa

mode





Tutorial explaining the ability to scroll text

Tutorial indicating the possibility of touching the details


Feet of the Pilgrims
Symbol of humility and toil, the swollen and dirty feet recall the penitential journey.


ITA
Gesù bambino
Nel gesto spontaneo della mano alzata, il Bambino dona la sua benedizione immediata.

07. FEEDBACK

7.1 Convergences & divergences between Primary & Further Research

The comparison of the results from Primary Research and those from Further Research highlights a series of significant convergences, as well as some divergences that enrich the overall analysis.

In terms of convergence, both levels of investigation highlight the inadequacy of the information tools traditionally used in sacred sites. International literature highlights how descriptive panels, brochures, and audio guides are often standardized and fail to foster a deep understanding of artistic heritage. Likewise, surveys, on-site observations, and analysis of reviews have confirmed the difficulty visitors face in decoding the symbolic meaning of the works. Both perspectives also acknowledge the potential offered by Augmented Reality as a tool that can enrich the visitor experience.

On the other hand, Divergences concern the nature of the issues highlighted. Primary Research focuses primarily on ethical and cultural aspects, such as the risk of spectacularization and commodification of sacredness. However, Further Research highlighted primarily practical issues, such as insufficient lighting, poor signage, and difficulties with physical and visual accessibility for specific categories of visitors.

This distinction enables us to observe how the literature provides an indispensable theoretical and methodological framework for guiding design decisions in terms of respect for the sacred context. The data collected in the field offer a concrete snapshot of the daily difficulties faced by visitors. The convergence between the two levels of analysis, therefore, strengthens the validity of the project proposal. The application must represent an innovative tool capable of overcoming the practical limitations of the visit; at the same time, it must operate within frameworks of ethical and cultural respect, ensuring a balance between technological innovation and the spiritual dimension of the religious heritage.

7.2 User Experience Evaluation

To validate the design choices and evaluate the effectiveness of the developed application, a user experience evaluation was conducted through a questionnaire. Visitors had the opportunity to directly test the prototype on site, at the Church of Sant'Agostino in Rome, interacting with Caravaggio's fresco The Pilgrim Madonna.

The questionnaire was elaborated based on established models and research on user experience evaluation in augmented reality and cultural heritage contexts. In particular, studies by Bekele et al. (2018) and Han et al. (2018) explore the dimensions of usability, perceived usefulness, aesthetic value, emotional engagement, and contextual coherence. This approach made it possible to structure the survey instrument according to parameters widely recognized in the literature, ensuring consistency and comparability with other similar studies. The questionnaire consisted of six thematic sections and included both Likert-scale and open-ended questions, allowing participants to express quantitative ratings as well as qualitative reflections on their experience.

The sample of participants consisted of 100 people, approximately 55% women and 45% men, with a mean age of 32 years (range 18–65). Visitors included both Italian citizens and international tourists, with about 40% residing in Rome or nearby areas and 60% being foreign visitors temporarily staying in the city. The group also presented a heterogeneous profile in terms of religious orientation, with around 30% identifying themselves as practicing believers and the remaining 70% motivated mainly by cultural and artistic interest. All participants had a medium to high level of education and a general familiarity with digital tools. Only 18% stated that they had previously used augmented reality applications, a figure that confirms the novelty and experimental interest of the proposed activity.

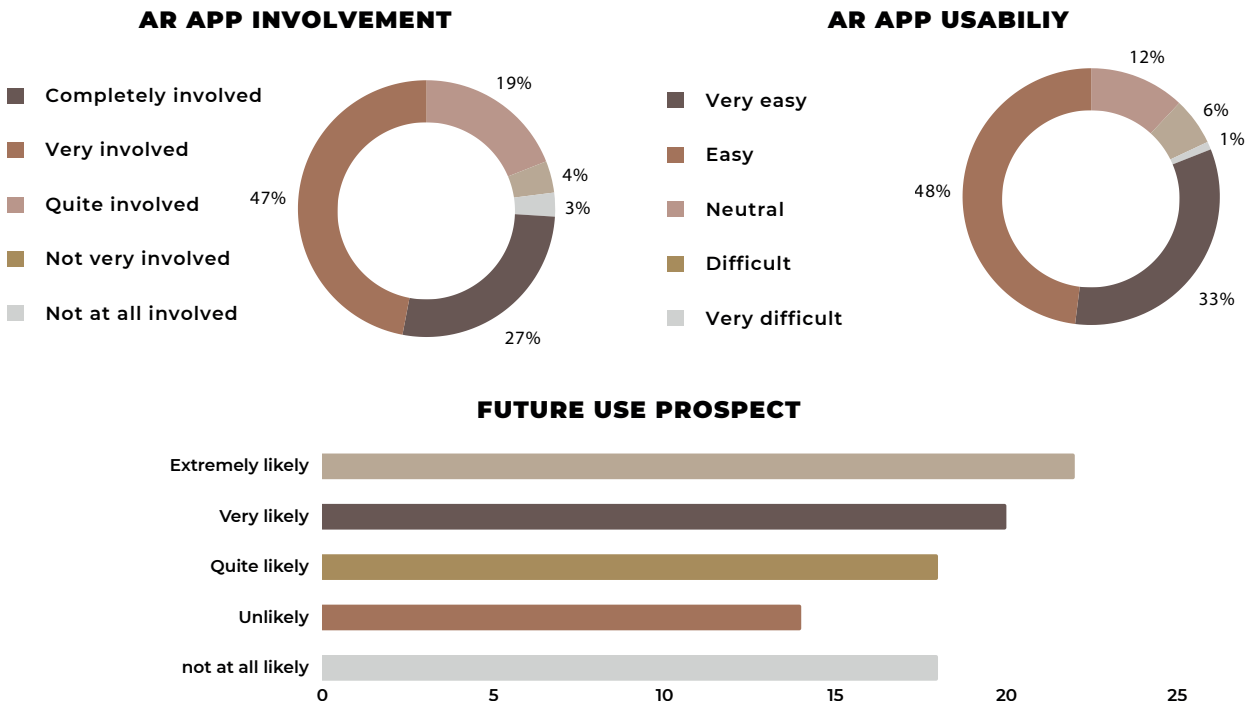


Figure 38 - Survey results pt.1

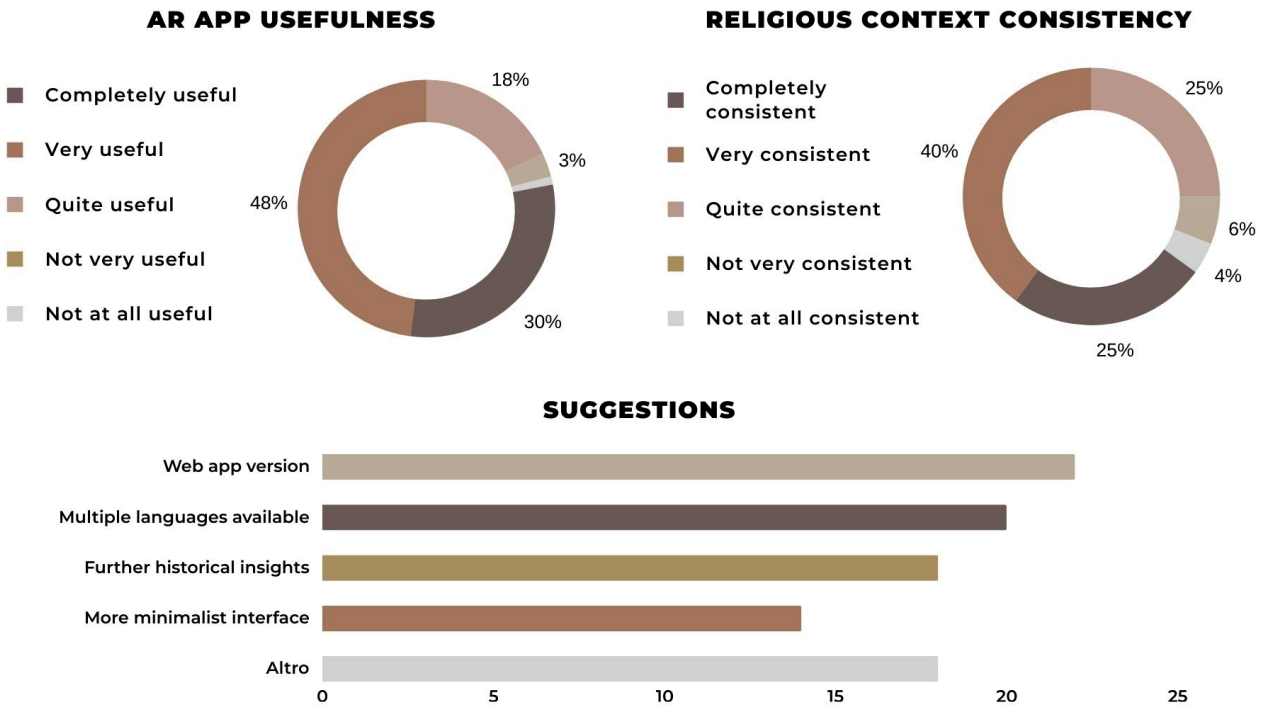


Figure 39 - Survey results pt.2

The test sessions were conducted individually to ensure a consistent experience and to minimize potential interference or distractions. Participants used a Samsung Galaxy A54 smartphone provided by the research team, equipped with the prototype application and configured to guarantee optimal performance and stable lighting conditions for image recognition. Before starting the test, each participant received a brief introduction explaining the purpose of the experiment and basic instructions on how to interact with the application. During the testing phase, there was an operator responsible for providing technical assistance and monitoring any interaction difficulties, without however intervening on the content or influencing the perception of the experience.

Each use session lasted about five minutes on average. The results presented in this section correspond to specific questions of the questionnaire, structured to analyze the main dimensions identified in the research phase. 78% of participants stated that the application improved understanding of the works and their artistic details, confirming their usefulness as a tool for cultural mediation. In relation to the comparison with traditional use, 62% said that the augmented reality experience significantly enriched the visit, indicating that technology complemented direct observation of the works.

Aesthetically and communicatively, 74% expressed a high level of involvement, describing the experience as more stimulating and immersive than a conventional visit. Regarding consistency with the sacred context, 65% of respondents perceived a harmonious integration between the technological dimension and the spiritual atmosphere of the church.

Finally, 81% of respondents rated the application as easy or very easy to use, while 67% expressed interest in being able to experiment with similar tools in other places of worship or museums. This correspondence between the questions of the questionnaire and the results presented allows us to understand in a transparent way how each piece of data reflects a specific dimension of the user experience, in line with the requirements identified in the research phase. The complete questionnaire is included in the Appendix, supporting methodological transparency and the replicability of the study.

08. REFLECTION

8.1 Critical reflection on the current limits and emerging opportunities for the design field

The experiment conducted demonstrates that Augmented Reality can act as a discreet cultural mediator, capable of broadening understanding and engagement without overpowering the artwork or the devotional context. Because it is effective, it exposes the project to stringent constraints that directly address the field of design.

The first concerns the sensitivity of the location, whereby animations, calls to action, and acoustic signals, which are effective in museum settings, can disrupt the tranquility and alter the ritual. This results in an extremely low intrusiveness threshold, which not only limits the expressive spectrum but also requires careful attention management to avoid slipping into spectacularization. A second limitation concerns the transferability of the results, because the validation was conducted on a fresco and in a specific Roman church despite the highly diverse surrounding landscape. Indeed, different spatial morphologies, more intense visitor flows, or different ritual cultures can profoundly alter the recognition yield and social acceptability of the intervention. Technical reliability itself is challenged by extreme environmental conditions in places of worship, such as uneven lighting, reflective surfaces, overhead work, and construction sites, which impact tracking and, consequently, the perceptual credibility of the layers. In addition, it is important to consider content maintenance. Historical, iconographic, and theological accuracy requires ongoing editorial governance, without which there is a risk of simplification or inconsistency. Moreover, there is the issue of accessibility: in real-world contexts, shaky-proof controls, rigorously verified contrasts, and eyes-free navigation modes are necessary, as well as strategies for users with varying cognitive loads. To sum up, AR introduces potential cognitive value but simultaneously creates a design challenge regarding the ethics of attention, technical robustness, philological care, and inclusion.

However, within these limitations lie concrete opportunities for the Design field. The first concerns the formalization of principles and patterns for "low-intrusive technologies," such as contained visual hierarchies, reversible mini-animations, contextual audio with conservative volume thresholds, and short timings. The second is a methodological opportunity based on co-design with the clergy, which can become a theological-cultural peer review structure capable of legitimizing the intervention and preventing conflicts of use. The third concerns the media structure: the multimodal and layered narrative with levels of depth, micro-explanations, and thematic paths allows the experience to be adapted to different profiles without overloading the environment. The fourth and final is the definition of metrics beyond traditional usability. Indeed, during the study, indicators were used that measure not only the tool's efficiency but also its ethical appropriateness to the context. For example, the study checked for perceived usefulness, coherence with the sacred, and observation time on the work.

Finally, in a strictly technical context, the architectural choice of separating content from code opens the way to portable infrastructures and shared editorial workflows between dioceses and superintendencies. It brings advantages such as source traceability and controlled updateability. In this context, the specific contribution of design is not to add information, but rather to develop replicable guidelines and content governance models that make AR not an end in itself, but a measured tool for curating and accessing heritage

8.2 Extensibility & future developments

The project offers high transferability beyond the experimental scope of minor Roman churches. The methodology, based on on-device visual recognition, modular content, and low-intrusion design principles, allows the experience to be extended to other ecclesiastical contexts, as well as museums and, with appropriate intercultural mediation, synagogues and mosques .

Technically, scalability is ensured by a reusable recognition pipeline for each artwork and an offline-first approach. Indeed, since the content architecture is managed through structured files, an evolution towards a semantic model with source traceability and editorial quality control is foreseen. Specifically, a simple, no-code authoring tool will allow curators, dioceses, and partner institutions to update texts, audio, and overlays without coding.

The expansion also requires strengthening accessibility and inclusion. An audio-first mode is planned, along with simplified, highly legible text, shake-proof controls, and a dark mode that respects dimly lit environments. The integration of non-invasive, LiDAR-based wayfinding will facilitate internal orientation and the location of artworks, eliminating the need for additional physical infrastructure.

On the functional front, future developments include 3D reconstructive overlays and photometric normalization algorithms to improve robustness and perceptual quality in adverse lighting conditions. Large-scale deployment of the solution requires optimal governance. Agreements with parishes, superintendencies, and museums are desirable. Sustainability could be based on mixed models: network licenses for dioceses and museum networks, cultural sponsorship, calls for tenders and European funds for the digitization of heritage, accompanied by a transparent estimate of maintenance costs compared to educational and conservation benefits. Some risks remain to be addressed: tracking reliability in critical situations, image rights management, security, and privacy. The mitigation strategy includes on-device processing, data minimization, periodic audits, and fully offline fallback plans.

Finally, an incremental roadmap is proposed. An initial evolutionary version will expand the number of languages and provide information functionality based on 3D reconstructions. A second evolution will introduce the concept of wayfinding and an authoring tool. Wayfinding serves to guide users in finding and recognizing frescoes within the space, while the authoring tool allows for easy sharing of associated digital content. A third version will enable a shared backend for site networks. In this way, the project will consolidate itself as a replicable platform for respectful mediation.

09. CONCLUSION

To summarize, this project investigated how Augmented Reality can enhance the understanding and enjoyment of frescoes in Rome's lesser-known churches while maintaining respect for the sacredness of the environment. The combination of theory, case studies, and in-situ experimentation demonstrated that AR, when designed with low-intrusion criteria, can act as an effective and unobtrusive cultural mediator.

On the empirical side, the usability test of the developed application, conducted in the Basilica of Sant'Agostino with 100 visitors, converges with the literature and on-site observations on three recurring issues of the visit: lack of information, perceptual difficulties, and language barriers. Furthermore, it demonstrates that AR addresses these gaps through artwork recognition, a contextual window, symbol highlighting, and multilingual support, reducing cognitive load and preserving the centrality of the actual artwork.

The project's original contribution is twofold. First, it provides an offline-first, modular, and scalable application platform that makes the experience robust and replicable. Second, a set of guiding principles translates the need to preserve the site's atmosphere into UX/UI choices. The consistency between principles and implementation has been verified in the field, with positive indicators of understanding, aesthetic appreciation, and future use intentions.

Despite the limitations discussed previously, the adoption of authoring tools for curators and site networks could consolidate the model and enable its extension to other heritage contexts, combining philological rigor, accessibility, and respect.

This does not conclude, but rather inaugurates a demonstration destined for international debate, demonstrating that Augmented Reality is a powerful tool and, in these contexts, the most effective and respectful option.

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