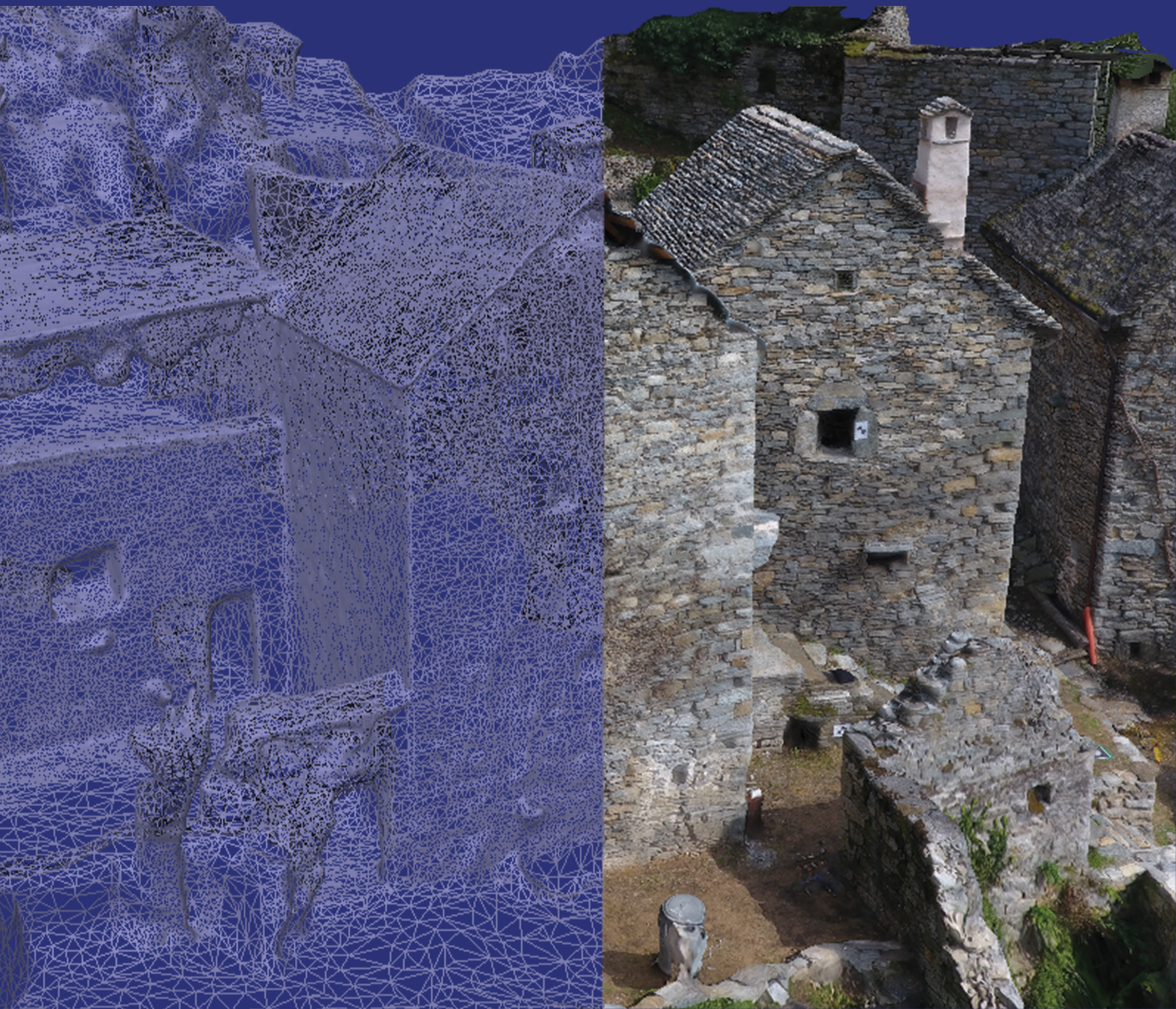


# Digital Immersive Applications for a Valorization Project of a Medieval Stone Village

*A Case Study of Ghesc*

Emy Rugel  
Mariana Tavares





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# abstract

This thesis explores the applications and uses of Augmented Reality (AR) and Virtual Reality (VR) technologies in the field of architectural visualization, considering their ability to valorize and reimagine cultural heritage sites. The medieval village of Ghesc, characterized by its traditional stone architecture, was used as a case study to develop three digital experiences with three different technological approaches: Immersal SDK, Unity VR and Spark AR. These experiences were designed not only for digital preservation but also to support the Canova Association activities as educational, dissemination and marketing tools. These three digital project ideas for the immersive access to the Ossola stone offer new approaches in which buildings can be preserved and promoted, thanks to innovative and engaging technological approaches. Finally, a comparison of the three projects is made, analyzing their uses, accessibility, and needs. The thesis concludes with final considerations and evaluations to plan future choices based on project requirements, technological limitations, architectural context and economic criteria when choosing the appropriate digital tools.

# 01

**introduction**

In the dynamic field of **architectural heritage preservation**, digital immersive applications offer an effective method to **valorize** and **reimagine** heritage sites. As digital technologies have evolved throughout the years, **Augmented Reality (AR)** and **Virtual Reality (VR)** stand out as tools that can not only help **digitally preserve heritage** buildings, but can also improve our knowledge and interaction with these historical sites. Using **Ghesc**, a historical stone village as the case study, this thesis highlights the various ways in which immersive applications can help as tools for **marketing, education and preservation**, in the field of architecture.

It is emphasized that the valorization project idea stems from involvement in the initiatives promoted by the **Ghesc-lab project** (winner of a **Fondazione Cariplo project - Luoghi da rigenerare**)

The goal of this thesis is to help the **Canova Association** create experiences that can enable visitors and stakeholders to understand and appreciate the historical significance of Ghesc's architecture. This was made possible by the effective use of AR and VR on different platforms. Every project was carefully selected based on how they would perform under different conditions. **Meta Spark AR** was used for its extensive accessibility on mobile devices, **Immersal SDK** for the creation of immersive location-based interactions, and **Unity VR** for the creation of immersive virtual tours. Together, all these projects demonstrate how technology can be used to enhance visitors' comprehension and appreciation of Ghesc's history.

By combining history, technology, and user experience, this thesis investigates how AR and VR might alter how we interact with and preserve the architectural stories of our past. It presents a future in which digital visualization will not only be an enhancing tool but also a major player in the ongoing narrative of cultural heritage.



# 02

**digital preservation,  
survey  
and applications**



Throughout history, people have been concerned with preserving architectural heritage, as this concept has evolved alongside changes in culture, society, and technology. Traditional architectural preservation methods frequently included **hand restoration work**, such as repairing or replacing decaying components, guided by craftsmanship and historical knowledge. Modern approaches, on the other hand, take into account scientific and technological advancements. To preserve authenticity while extending the life of the building or site, they prioritize **documentation**, **structural research**, and the use of **contemporary materials**. (Facchi, Grimoldi, & Landi, 2022)

In recent decades, there has been a trend toward the use of digital technologies such as **3D modeling** for digital preservation. These technologies provide precise measurements and visualization of architectural features, assisting in restoration and maintenance activities. (Aziz & Siang, 2014)

Preservation of architectural heritage is critical for a variety of reasons, including cultural identity preservation, educational possibilities, and tourism promotion. However, it is fraught with difficulties, from limited resources, to environmental risks, and balancing preservation with modern development.

# architectural heritage preservation



**Figure 2.1**  
Ghesic's location - the north of Italy.  
(Elaboration by the authors)

## THE PROJECT SITE LOCATION

Located in the far north of the Piedmont region, almost reaching Switzerland, the **Ossola Valley** is defined by the alpine natural landscape, with vegetation belts associated with dramatic fluctuations of elevation. (fig. 2.1) Historically, this has always been a place of passage, serving as a link between the Mediterranean and continental Europe. In previous times, this has permitted a constant flow and exchange of knowledge, as well as the influence of new innovative trends, reflected in the buildings typical of the area. Being part of the Alps, the large mountain chain that stretches across the continent, Ossola is characterized by the art of **stone architecture**, emphasizing the fundamental importance of the Alps as a site of cultural relevance. (fig. 2.2)

Although there is plenty of evidence from earlier time periods, the majority of the buildings that are still standing today can be dated back to the early **Middle Ages**. It is no surprise that the medieval era signaled a turning point in traditional construction methods by establishing the transition from less durable materials, such as wood and thatch, to the predominant use of stone. The spread of Christianity through Europe is one of the many factors that welcomed this transformation; with the need to build new churches, sculptors, master masons, and stonemasons traveled throughout Italy and Europe, leaving their footprint on local culture, with their knowledge in the art of building with stone, contributing to the switch from the old classical, Byzantine style construction to the new Romanesque

architecture.

Over the years, the Ossola residents have been able to construct solid and durable houses, using only the few, simple resources available locally. Even without renowned architects, an architectural statement rich with elegance and beauty arose spontaneously. Despite the profound impact of the Second World War and the introduction of modern concrete construction, to the modern visitor, Ossola seems to be mainly preserved under centuries of layers of material culture, thus making the preservation and protection of Ossola's architectural and cultural heritage a mission of great importance. (Cesprini, 2015)



**Figure 2.2**  
Villages scattered along the  
Ossola Valley. (VisitOssola,  
2024)

## THE CANOVA ASSOCIATION

This is how the **Canova Association** came to be, back in 2001, born out of a desire to improve and promote respect for Ossola's historical architectural heritage. Named after a small medieval village in the Ossola Valley, specifically in the municipality of Crevoladossola, where a massive restoration movement began in the early 1990s, this non-profit organization was created with a mission to restore and revalue rural medieval stone architecture, sparking the debate about the belief that old stone structures can provide more humane and sustainable dwelling solutions.

The village was completely abandoned, with some buildings reduced to ruins. It was the former president of the association Ken Marquardt and his wife Kali who launched the hamlet's rehabilitation project, by

acquiring the first building, shortly followed by others, both foreigners and Italians. (Cesprini & Marquardt, 2020) The American couple recognized the authenticity and attractiveness of this area, full of history but almost forgotten, an ideal environment for the beginning of a new life. The primary aim was to revive this location by restoring its dignity, starting with its ruined buildings, and designing a model of restoration that might be used for the rest of the valley. Two decades later, this experiment can be considered a complete success, not only with the resurrection but also with the notoriety of the village of Canova outside of the confines of Ossola.

The association has also been organizing school camps on the subject of architectural restoration, having collaborated with universities from Italy, France, Japan, Palestine, Canada, and the USA. Over 60 professionals have been invited as well to Ossola, organizing conferences regarding restoration and sustainability, bringing awareness to the importance of this mission. World-renowned architects such as the Herzog & De Meuron Studio have been present at this event over the years.

The students have the opportunity to learn the techniques of typical Ossola architecture, gaining empirical knowledge on-site. The early projects involved historic public buildings in need of refurbishment, such as the re-roofing of many wash-houses with stone roofs, repairing a small bridge, and intervening on an old watermill. (Cesprini, 2015)

## THE LABORATORY VILLAGE OF GHESC

In the past years, the camps have been held in Ghesc, a medieval village abandoned for over a century, the ideal location for organizing study and research activities on the subject of traditional stone architecture. (fig. 2.3) The students participate in lectures and tours relevant to the area and history of Ossola, getting a comprehensive picture of the local culture. The school camps are important for both intercultural interchange and local awareness, but they also provide an opportunity for revitalization and rediscovery of lost locations. (Campi Scuola, 2024)

**Ghesc** (term used in local dialect, 'Ghesio' in Italian), a settlement in the picturesque mountains of Piedmont in the municipality of Montecrestese, is just a few minutes away from the Canova Village. Despite being abandoned since the late 1800s, almost completely ruined after years of neglect, Ghesc is now experiencing a second life thanks to the efforts of the association. The hamlet consists of eight stone dwellings, one of which still maintains its original roof, while the other ones were almost entirely collapsed.

The current president of the association, the scholar of traditional stone architecture Maurizio Cesprini and, the architect Paola Gardin, also a member of the association, are rebuilding this hamlet to its former glory, always prioritizing and respecting the nature and tradition of the place. In 2007, Maurizio and Paola bought one of the eight residences in the settlement, the 'Casa Alfio', and later moved there in 2012. (fig. 2.4) Their methods centered on improving what



Figure 2.3  
Entrance of Ghesc, 2023. (Photo by the authors)

was already there and using sustainable resources. Three years later, their work on the property was recognized in the International Award for Sustainable Renovation and Construction in the Alps.

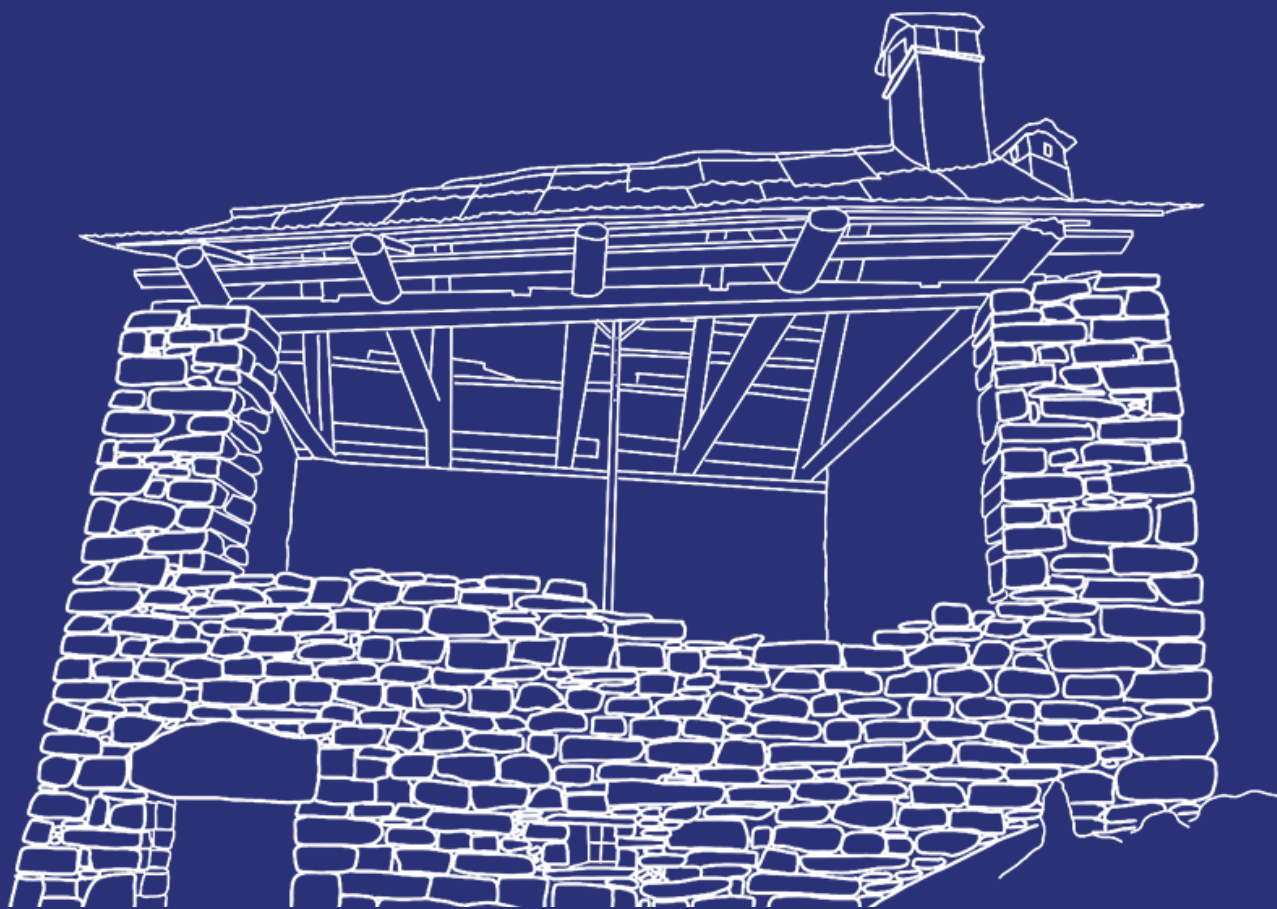
Ever since 2010, the Canova Association has formed a number of partnerships with universities, turning the village into a true open-air laboratory, as well as a cultural center that hosts a variety of artistic events and activities. Each year, groups of students come to join a summer work camp, with the mission of rebuilding this ancient settlement. (fig. 2.5) (Angeloni, 2022)



**Figure 2.4**  
Ghesc in 2013: Small House (left), Casa dell'Associazione (center) and Casa Alfio (right).  
(Photo by the authors)



**Figure 2.5**  
Ghesc Workshop with Willowbank School of Restoration Arts, 2011. (Photo by Canova Association's personal collection)



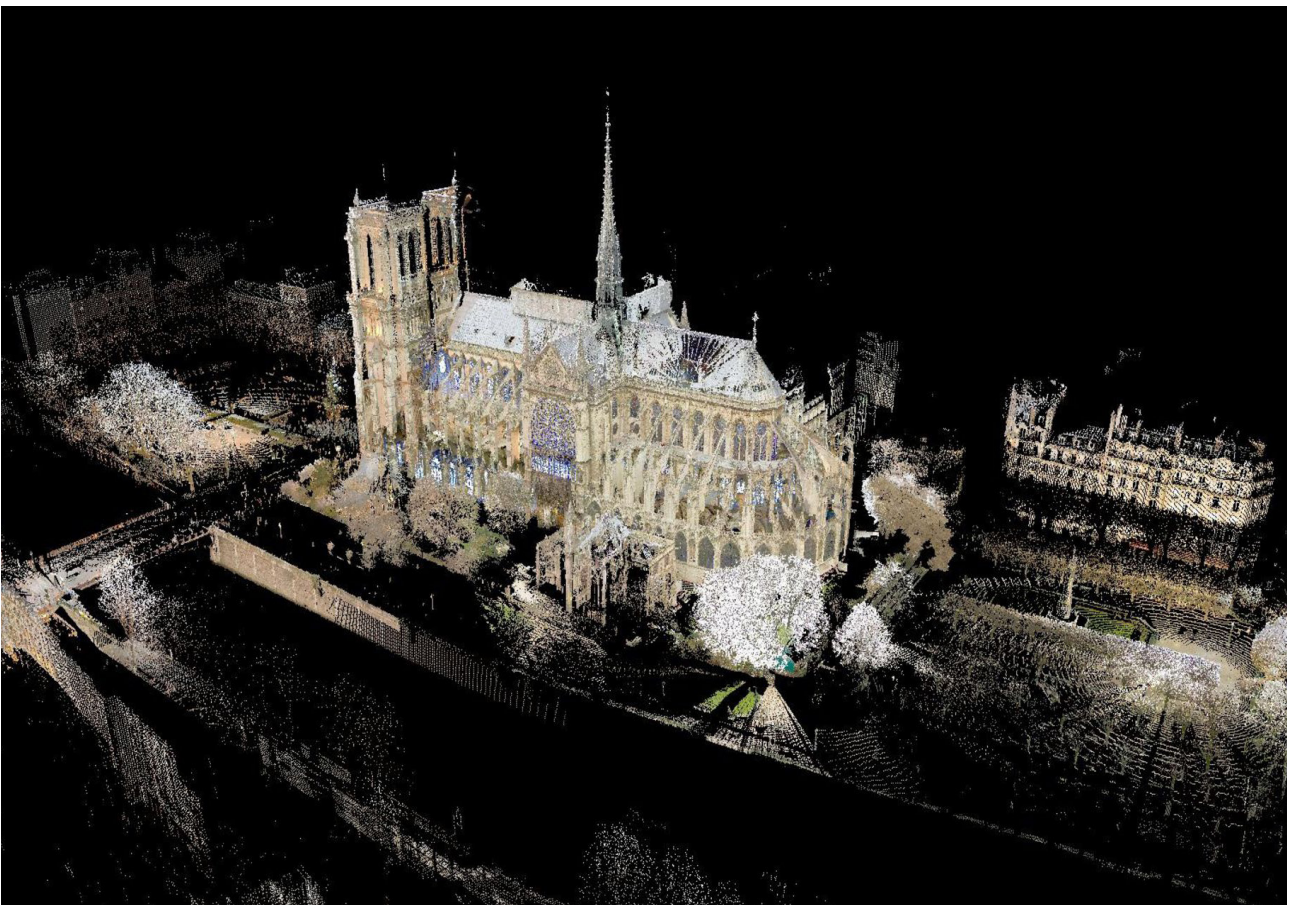
# digital survey

## DIGITAL ARCHITECTURAL SURVEY

Within the rapidly evolving field of architectural conservation, digital architectural survey is a notable tool that has transformed the process of documenting and preserving architectural heritage. This approach has become fundamental not only for its importance in cultural preservation, but it has also proved to be an advantage in different fields, such as education and marketing.

### Cultural Preservation

Digital architectural surveys serve as an essential tool for gathering detailed information about historical buildings. They not only provide an accurate, three-dimensional record of buildings, but they can also offer insights into the buildings' construction methods, and historical context. The data gathered becomes essential for restoration efforts and it ensures that every architectural detail is recognized and kept for future generations. A survey should not be conducted only when there is a will to rebuild, but even before a catastrophe hits, preventing the permanent loss of humanity's past. The Notre Dame Cathedral is an example of the importance of having a digital survey for preservation. After the tragic fire that took place in 2019, the laser scanner survey, which was done by the late art historian Andrew Tallon, has played a crucial role in the restoration process of the Cathedral. (Lou, 2019) (fig. 2.6)



**Figure 2.6**

Notre Dame, Paris: digital data recorded by Professor Andrew Tallon at Vassar College, New York, USA. (Lou, 2019)

## Marketing Purposes

Digital architectural surveys can also offer a strong business opportunity for marketing heritage sites. From these surveys, virtual tours, interactive models, and augmented reality experiences can be developed to help attract tourists and stakeholders, increasing public awareness and funding for restoration or conservation initiatives. Additionally, having digital representations of a site can help break down geographical barriers, allowing people to experience the site from across the globe. An example of this is the famous Guggenheim Museum Bilbao, designed by Frank Gehry. The museum adopted modern technology by offering virtual tours on its website to increase its global presence and draw tourists. (Guggenheim 365) (fig. 2.7)

Another case is the Louvre's VR Mona Lisa Experience. Through a VR headset, viewers can explore the artwork in a vivid 3D environment while learning new information about the Mona Lisa and its creation. This experience refreshes the relationship with the famous Mona Lisa by drawing in a new audience and enhancing its marketing appeal. (Louvre, 2024) (fig. 2.8)

A similar case study can be seen with the Duomo of Milano. This experience provides the audience with AR or VR devices that allow them to have an interactive and immersive experience. (Duomo di Milano, 2023) (fig. 2.9)



Figure 2.7  
Guggenheim 365: Guggenheim Museum Bilbao, Spain. (Guggenheim Museum Bilbao, 2024)



Figure 2.8  
Louvre's VR Mona Lisa Experience (Louvre, 2024)



Figure 2.9  
AR Experience at the Duomo of Milano (Duomo di Milano, 2023)



**Figure 2.10**  
Rome Reborn. (Fischer, 2023)

### Educational Purposes

Another important use of digital surveys can be seen within educational institutions to enhance the learning experience by making them more dynamic and interesting. Without requiring actual access to the location, students can virtually analyze architectural elements, making educational experiences more accessible, regardless of one's location.

An exciting example of this is the project Rome Reborn, by The UCLA Cultural Virtual Reality Laboratory (CVRLab). (fig. 2.10) Their goal was to reconstruct the entire ancient city of Rome, from the Iron Age to the Gothic Wars. They have been able to create 3D digital reconstructions of various elements of the city such as the Roman Forum, and all these models have been used as educational tools in architecture and art classes at UCLA. (Frischer, 2003)



**Figure 2.11**  
4DGypsoteca, infographic simulation (Belardi & Menchetelli, 2018)

Another interesting example can be seen with the project 4DGypsoteca. This project involves the digital scanning acquisition of works preserved in the plaster cast gallery of the Academy of Fine Arts of Perugia. (fig. 2.11) These digital models can be used not only for 3D printing purposes, but also for educational purposes to provide an immersive drawing learning experience where students can learn the fundamentals of academic drawing. (Belardi & Menchetelli, 2018)

The virtual classrooms offered by Frank Lloyd Wright's Foundation are another example of how digital tools can be used for educational purposes. The Foundation offers teachers many resources such as virtual tours of Frank Lloyd Wright's projects where students can get a more interactive and immersive educational experience. (Frank Lloyd Wright Foundation, 2024) (fig. 2.12)



**Figure 2.12**  
Taliesin West Digital Experience (Frank Lloyd Wright Foundation, 3D laboratory, 2024)

Ghesc can be seen as a great example of the value of 3D architectural surveys for the preservation and development of historical architecture. As part of a teaching and training program, the 3D Survey Group of Politecnico di Milano, together with the Canova Association, organized several summer schools throughout the years called “Laboratory of Places 2017— Ghesc and surroundings — history, survey, evolution”. (Laboratory of Places, 2011-2016) These workshops have used different techniques and tools such as laser scanners, aerial and terrestrial photogrammetry. (Achille et al., 2018) These surveys have helped document and support the development of the site. Additionally, the varying data quality and output of these surveys reflect the evolution of surveying technology.

**Figure 2.13**  
Plan of Ghesc  
Scale 1:500  
(Elaboration by the authors)



# ghesc survey

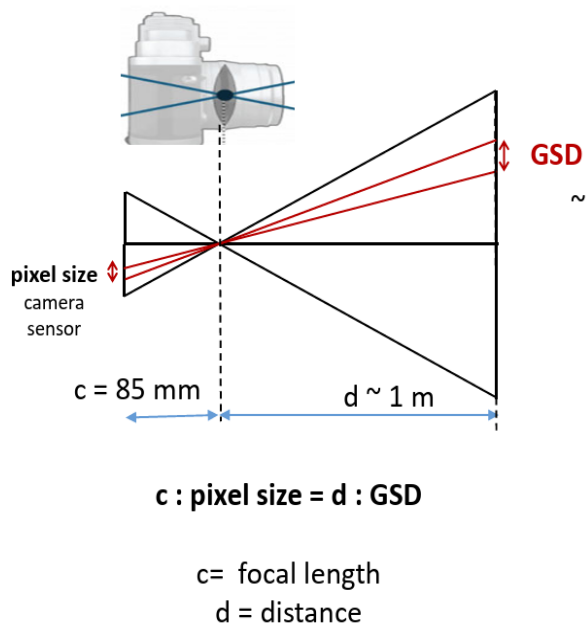
## EXISTING DATA:

### DIGITAL SURVEYS OF THE SITE OVER THE YEARS

The summer school's data from the years 2012, 2016, and 2017 is currently available. It is interesting to look at this data as it illustrates the development and evolution of the restoration work in the Ghesc village, but also of the digital survey techniques (laser scanning and photogrammetry). Resolution, accuracy, and texture generation ease all appear to have improved when comparing point clouds and 3D models produced throughout these years.

“**Laser scanning** is an active, fast and automatic acquisition technique using laser light for measuring, without any contact and in a dense regular pattern, 3D coordinates of points on surfaces” (Grussenmeyer et al., 2018).

**Photogrammetry** is a technique that uses images captured from different angles to create precise 3D models, employing the same principles of stereoscopy (Bolognesi & Fiorillo, 2019)



**Figure 2.14**  
How to evaluate maximum working distance considering sensor size, GSD and focal length. (Fiorillo, 2024)

**Ground Sample Distance (GSD):** The distance between the centers of two consecutive pixels measured on the ground. The GSD is critical for defining the resolution of the images and in turn, defining the final resolution of the photogrammetric output. The lower the GSD, the better the resolution would be as it means that each pixel represents a smaller area of the ground. (Bolognesi & Fiorillo, 2019)

From our case study there were two three-dimensional digital techniques used: laser scanning and photogrammetry.

Laser scanning is an active sensor-based range system while photogrammetry is a passive sensor-based image system. (Guidi, Russo, & Beraldin, 2010; Remondino, 2011)

Laser scanning's acquisition images often have lower qualities when compared to photogrammetry. Furthermore, alignment issues between the laser placement and the camera can make it difficult to align the photos with the point cloud. The accuracy, point resolution, and acquisition range of laser scanning technologies are different, and no single device can be used for all survey scales or representations. On the other hand, photogrammetric techniques stand out for their portability and affordability, with some consumer-grade cameras being suitable for use. (Bolognesi & Fiorillo, 2019) Photogrammetry has been greatly improved by the development of computer vision algorithms, which have added flexibility by automating formerly difficult and time-consuming processes in the image matching and calibration stages. (Fassi & Campanella, 2017) The main difference between laser scanning and photogrammetry is how 3D reconstructions are achieved. Laser scanning will capture 3D objects as point clouds, while photogrammetry will create a complete 3D object. The final quality of the 3D model will depend on the original photographic quality and the captured geometry. (Fassi, 2013)

To produce accurate models with photogrammetry it is necessary to have technical knowledge on how to take quality photos and data processing for creating precise models. (Menna et al., 2016). For example, the data survey done in 2017 was designed focusing on two important elements such as image network geometry and **GSD** (Ground Sample Distance). (fig. 2.14)

To ensure that the final graphic representation was at the appropriate scale (1:20), the minimum GSD in the case study was set at 4 mm. Taking into account the size of the camera’s sensor and the focal length of the lens, the formula  $d = GSD \times f / \text{pixel size}$  was used to calculate the maximum capture distance from the subject. The focal length and distance for the survey were selected based on a GSD value reduced to 2mm, above the minimum standards, for safety and to guarantee superior resolution. (Bolognesi & Fiorillo, 2019)

### 2012 Survey

This survey was obtained using the **3D Laser Scanners**, LEICA HDS7000 and LEICA – C10. Laser scanners enable the precise capture of surfaces by producing **3D point clouds** that reproduce real dimensions of the geometry and its surroundings. However, as its main purpose is to record data based on distance measurements, they do not record colors or texture information, except when coupled with a camera. In particular, the first laser scanner models were not initially designed to be equipped with a camera. (Grussenmeyer et al., 2018) It was only later that external cameras or integrated cameras were devised, which in recent years have arrived at high resolutions. Therefore, the data obtained from this survey only allowed for the creation of 3D Models without realistic textures. (fig. 2.15)

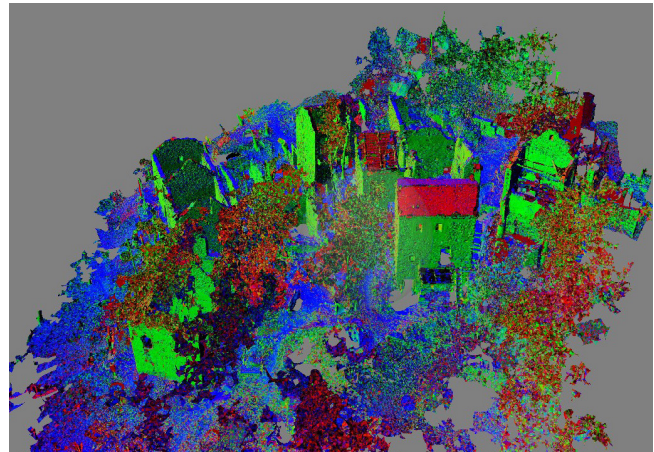


Figure 2.15  
2012 Laser scanner survey of ghesc. (Dataset from students of Laboratorio dei Luoghi 1° edizione)

### 2016 Survey

There were several surveys done this year with **terrestrial** and **aerial photogrammetry**. The data gathered from these surveys had been previously imported into the photogrammetric software **Agisoft Metashape** (<https://www.agisoft.com>), to build the dense point cloud from which we started to work from. For this thesis, we chose 2 of the surveys from 2016 as they contained all the buildings needed to create the different experiences. The survey done with camera NEX-6 provides data of the whole site while the survey done with Nikon and Phantom provides data for Small House with a higher resolution. (Table 2.1) (fig. 2.16)

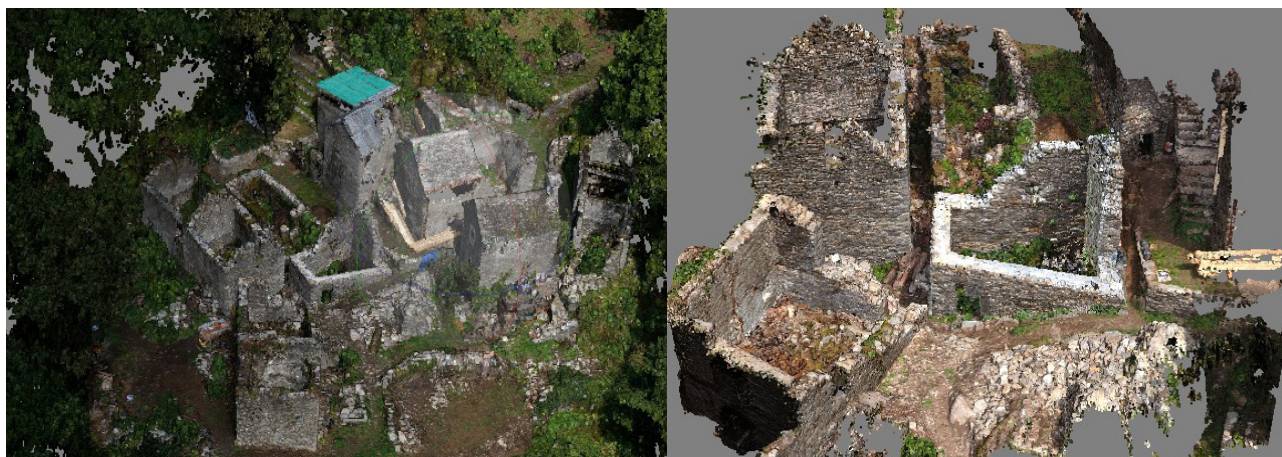
### 2017 Survey

There were also several surveys done this year with terrestrial and

Camera	Pixel Size (mm)	Focal (mm)	N° of photos	Resolution	Average GSD (mm)
NEX-6	0.004	20	128	4912x3264	10.6
NIKON D810	0.004	24	169	7360X4912	0.3
PHANTOM DJI		3.61	33	4000X3000	

Table 2.1

Technical Data of the digital surveys from 2016. (Data from students of “Laboratorio dei luoghi 2016. Ghesc e dintorni. Storia, Rilievo, Evoluzione. Summer school: il rilievo per i Beni Culturali”)



**Figure 2.16**

Left: Whole site, 2016 survey. Right: Small house, 2016 survey. (Dataset from students of “Laboratorio dei luoghi 2016. Ghesc e dintorni. Storia, Rilievo, Evoluzione. Summer school: il rilievo per i Beni Culturali”)

aerial photogrammetry from which we only needed 3 to create our experiences. The survey done with the camera Phantom provides a survey of half the site of Ghesc while the survey done with Canon provides a smaller site of Ghesc but with higher resolution as they were done with terrestrial photogrammetry which can provide a lower GSD. Lastly, the survey done with Nikon was interesting as it provided a survey of the interior of one of the rooms of Casa dell’Associazione. (fig. 2.17) (Table 2.2)

Camera	Pixel Size (mm)	Focal (mm)	N° of photos	Resolution	Average GSD (mm)
PHANTOM DJI FC330	0.001	3.61	119	4000X3000	2.4
NIKON D3100	0.005	18	265	4608x3072	0.3
CANON EOS 70D	0.004	18	804	5472X3648	0.4

**Table 2.2**

Technical data of the digital surveys done in 2017. (data from the students of the Laboratory of Places 2017— Ghesc and surroundings — history, survey, evolution”)



**Figure 2.17**

Left: Half Site, 2017 survey. Middle: Associazione, 2017 survey. Right: Teatro & Affresco, 2017 survey. (Dataset from the students of the Laboratory of Places 2017— Ghesc and surroundings — history, survey, evolution”)

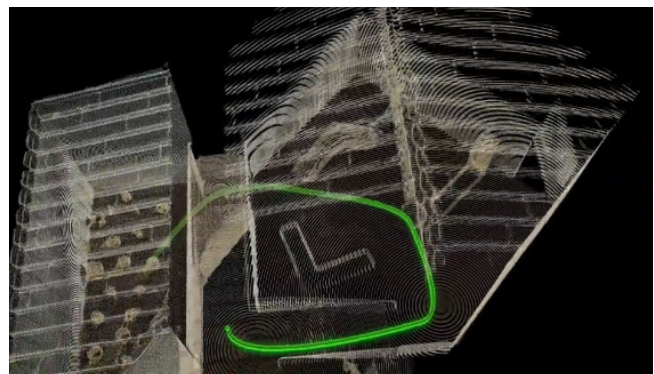
## NEW DIGITAL SURVEYS: MOBILE SCANNING AND IMMERSAL

A state-of-the-art portable image laser scanner makes it simpler to generate a 3D digital twin while on the go. The **Leica Geosystems BLK2GO handheld laser scanning system** (fig. 2.18) is designed for quickly capturing environments with ease. This portable scanner records photos as well as poses created by the system to better develop a visualization map. What makes the BLK2GO so effective is its one-button operation: simply turn it on, walk around, and watch as millions of precise data are gathered to recreate the scene in vivid 3D realism. By eliminating the need for a tripod and a skilled operator, this instrument drastically reduces the amount of time required for on-site planning and scanning. With its quick and simple scanning speed for huge buildings, structures, or environments, the BLK2GO is a significant technological improvement for surveying. The BLK2GO combines an **IMU** and both **LiDAR** and **Visual SLAM**, into a single, powerful device. Thus, to fully grasp the scope of its capabilities, we must first return to the basics and understand these three technologies behind it. (Leica Geosystems, 2023)

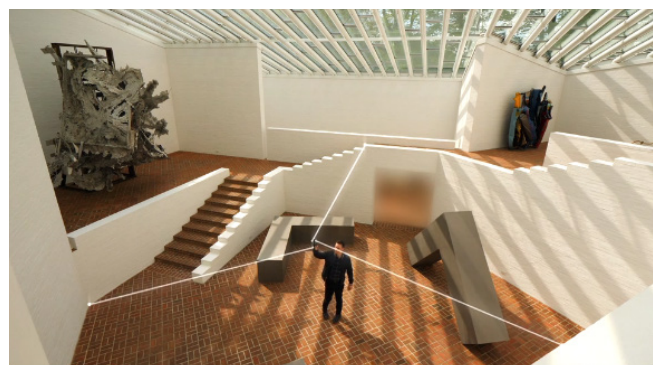


**Figure 2.18**  
Leica BLK2GO.  
(Leica Geosystems, 2023)

First, the IMU - **Inertial Measurement Unit** - is a device typically consisting of multiple sensors, from accelerometers to gyroscopes, that work together to provide accurate information about the scanner's change of position in three-dimensional space, by measuring and recording its velocity, orientation, and acceleration. (VectorNav, 2024) LiDAR stands for **Light Detection and Ranging**, a method that functions similarly to radar but uses infrared pulsed laser instead of radio waves, to calculate a distance by targeting a surface or an object and measuring the time for the reflected light to return to the receiver<sup>1</sup>. (Velodyne Lidar, 2024) (fig. 2.19) These laser measurements are tracked by the IMU in space and time, building up a point cloud. (Leica BLK Original, 2022) The **Simultaneous Localization and Mapping** (SLAM) localizes the position and orientation of the capturing device with respects to its surroundings, while at the same time it captures a spatial map of the environment where it's located. (Thrun, 2007) SLAM technologies comes in many forms, some of which don't even use cameras. Visual SLAM is a variation of SLAM system that uses 3D vision to map the environment and locate the sensor where these locations are unknown. (Vision Online Marketing Team, 2018) (fig. 2.20)



**Figure 2.19**  
LiDAR SLAM function: BLK2GO path (represented as a green line) to survey a building. (Leica Geosystems, 2023)



**Figure 2.20**  
Visual SLAM function: the three cameras trajectory (represented with white lines) - taking panoramic pictures of the surroundings. (Leica Geosystems, 2023)

These individually complex technologies together combine into the BLK2GO scanner, taking pictures every second and, by means of AI, they allow the device to triangulate itself to its specific location. These three systems when functioning together are what's called **GrandSLAM**, a market-leading type of SLAM that can

<sup>1</sup>This is typically how laser scanner devices work.

gives the flexibility to just walk through an environment and capture it in 3D. (Leica BLK Original, 2022)

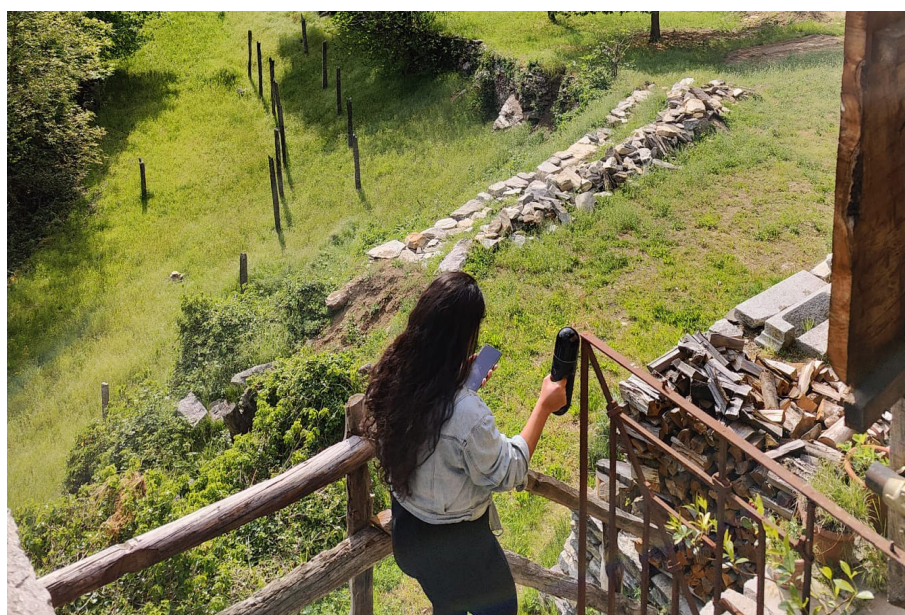
To recapitulate:

The LiDAR SLAM gives the BLK2GO the capability to identify “[...] different surfaces and unique geometry in the LiDAR data, which it analyzes to calculate its 3D position”. The Visual SLAM consists of “three panoramic cameras [that] identify similarities between consecutive images to calculate the scanner’s movement through 3D space”. And finally, “while you walk, the IMU [...] senses your movement to calculate the BLK2GO’s change of position in 3D space. (Leica Geosystems, 2023)

To operate this tool, we initially strategized various scanning **paths**. We conducted multiple scans along a total of 10 paths through Ghesc, ensuring overlaps in certain areas to enhance the scanner’s accuracy. Each path’s scanning duration was relatively short, taking approximately 5-15 minutes. (fig. 2.21)

Once finished, the scans can then be exported from the BLK2GO directly to Leica’s Cyclone Register 360, a 3D Laser Scanning point cloud registration software, to clean noise out of the scans, remove moving objects, join scans together, and export different point cloud formats.

However, for the purpose of this thesis we decided to collaborate with **Immersal**, a visual positioning technology company, typically focused on location-based AR. After we captured the data, the scans were uploaded to Immersal’s developer portal where they are converted into two different maps - a detailed point cloud and a simplified mesh - that can be imported into any compatible software.



**Figure 2.21**  
Scanning Ghesc using the BLK2GO system. (Photo by the authors)

## EXTENDED REALITY

Extended Reality (XR) is an umbrella term that encompasses a spectrum of immersive technologies - mixed, virtual, and augmented realities - as well as those yet to be developed. (fig. 2.23) These technologies extend our reality by merging it with digital content to different degrees, creating a diverse range of immersive experiences. XR technologies have the power to completely change the way people interact with each other and the world surrounding them. Some experiences are starting to expand from the typical visuals to incorporate other senses, such as sound, touch, and smell, quickly pushing the boundaries between the real and artificial.

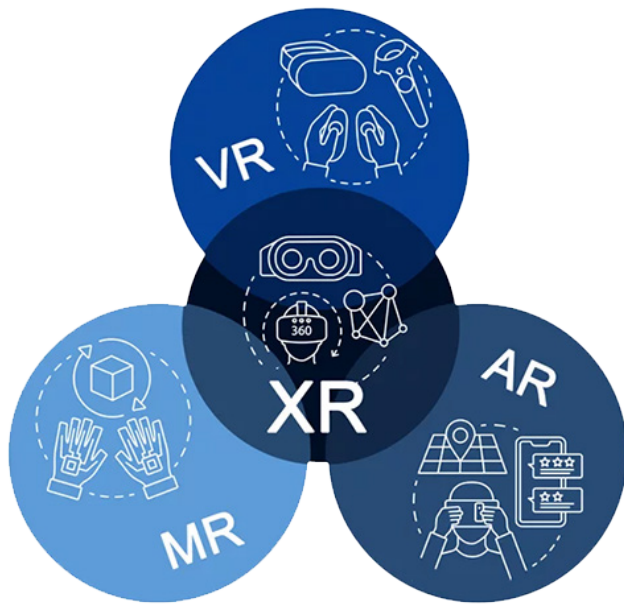
In Mixed Reality (MR), digital and physical items coexist and can interact in real time. Out of the three, this is the most recent immersive technology, sometimes referred to as a hybrid reality since it incorporates both worlds. It requires significantly more processing power compared to VR or AR. (Marr, 2019) In MR, virtual objects appear as holograms in the real world, displayed through an MR device (e.g a headset), with which the user can interact using gestures and voice control. (Teruggi and Fassi, 2021)

A great example of this is the application of this technology in the Milan Cathedral, a project developed by Simone Teruggi from Politecnico di Milano's 3D Survey Group, with the goal to catalog and exchange vital data and documentation regarding the state of the cathedral, to better inform and prepare the professionals involved in the process of its conservation. (Teruggi and Fassi, 2021) (fig. 2.22)



Figure 2.22  
MR point cloud interaction with the Milan Cathedral. (Teruggi & Fassi, 2021)

# digital applications



**Figure 2.23**  
 “Extended Reality (XR) is the family that includes Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) either utilized individually or simultaneously.” (Envision Innovative Solutions, 2024)

## AUGMENTED REALITY

In **Augmented Reality (AR)**, a digital layer of virtual objects and information is overlaid in the real world, enhancing the physical reality with the use of text, images, and animations. (fig. 2.24) To place an object in the real world, first, its exact location must be decided. An AR app uses the information of the real world received from a device’s camera, such as the detection of planar surfaces, people, objects, faces, and so on, in order to be able to develop a good experience for the user. To access this experience, there are a variety of devices that can be used, such as AR glasses, smartphones, tablets, and displays. The use of these devices implies that the users are not cut off from the actual reality and can still engage with it and see what is happening around them. The global phenomenon that was the Pokémon Go game, which makes digital creatures appear on mobile phones while recording their surroundings with their cameras, and the app Snapchat’s filters, which place virtual objects such as hats or sunglasses on the user’s face, are two of the most commonly known uses of AR. (Vigliarolo, 2019)

### Types of Augmented Reality

AR technologies can be essentially separated into two main categories: marker-based and marker-less. What fundamentally differentiates them is the way the digital content can be triggered and displayed in the first place.

**Marker-based AR** requires a target, typically an image or a QR code. The device’s camera recognizes the image and projects the virtual objects that have been previously programmed into the device or



**Figure 2.24**  
 Example of an Augmented Reality experience, accessed through a smartphone. (Martinez, 2024)

application. The marker also helps to determine the device's position and orientation in the space by acting as a reference point in the field of vision of the camera. After reading the target, it compares it to the others that are stored in its information bank until it finds a match, using that data to determine the pose and correctly position the AR content.

**Marker-less AR** on the other hand is more complex since it operates without a reference for the device to focus on. As a result, the device has to be able to discern items as they appear and recognize the object using a recognition algorithm that analyses colors, patterns, and other visual features. Afterward, by utilizing data from GPS, accelerometer, time, and compass, it will use a camera to overlay an image of whatever is desired in the real world. Marker-less technologies include geolocated AR, when an experience is based on GPS positions, or by tracking different elements, from the human body, to objects, and to any kind of surfaces, placing the AR content anywhere, even floating in the air. (fig. 2.25) (Martínez, 2024)

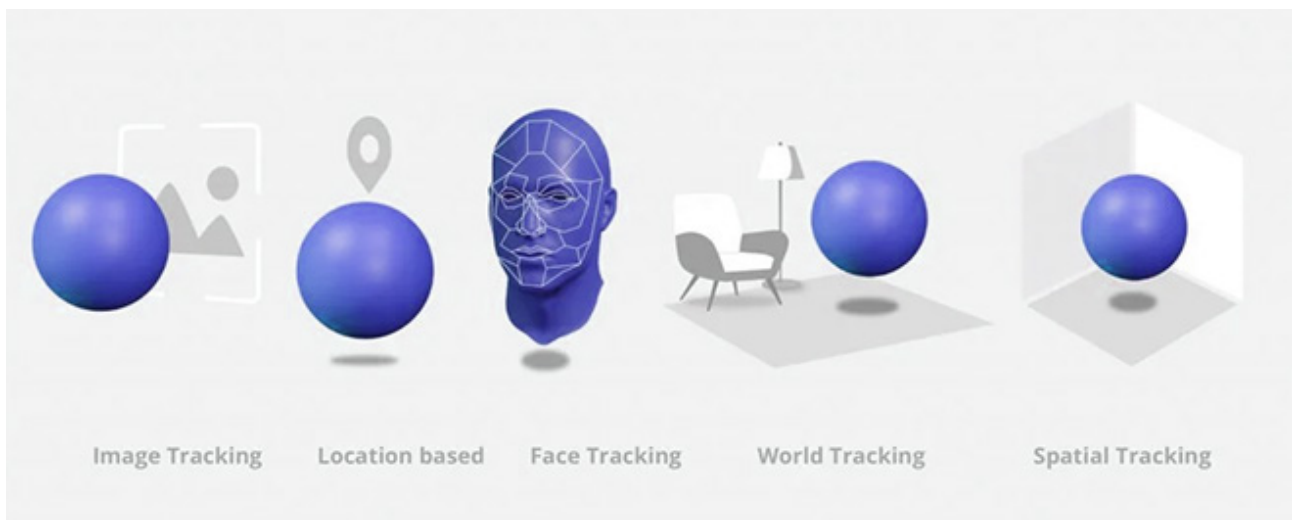


Figure 2.25  
Types of Augmented Reality. (Martínez, 2024)

## VIRTUAL REALITY

Contrary to augmented reality, **Virtual Reality** (VR) creates a completely simulated, digital, three dimensional environment that is fully immersible. With only a VR headset - or any head-mounted display - the user is transported to a 360° view of a computer-generated world - almost as if they are actually there. VR works by rendering a digital environment, created by tracking the user's head and body movements, matching them in real-time. This creates an illusion of the user physically being in that space, allowing them to interact with objects and other elements in that digital world. (fig. 2.26)

Although this technology was mostly seen being used in industries such as gaming and entertainment, nowadays it is such a popular application that more and more fields are using it, including engineering and construction, healthcare, the military, to name a few. As the technology keeps advancing, these environments will keep looking more realistic and adaptive, pushing the boundaries between the real world and the virtual world. (Weinstein, 2022)



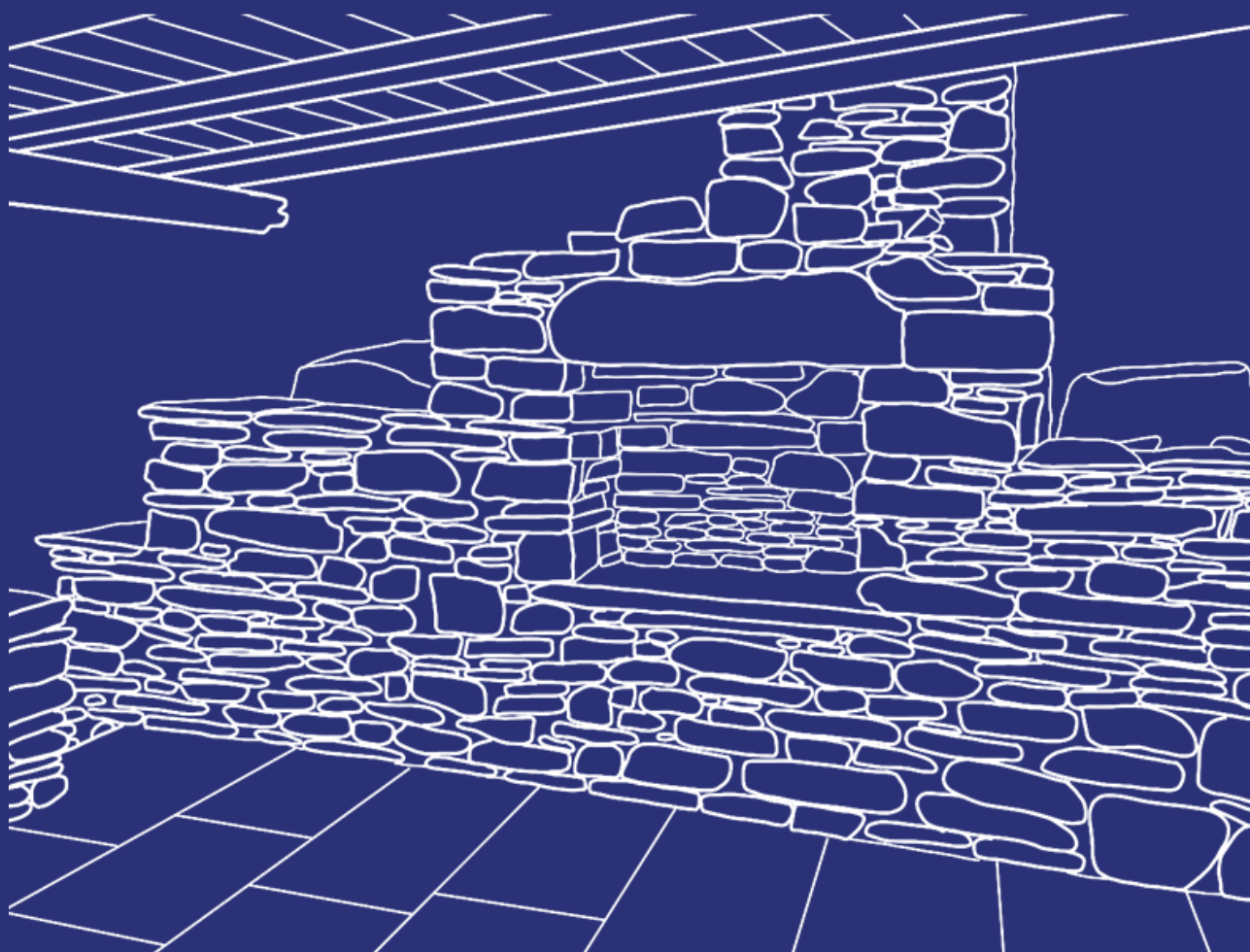
**Figure 2.26**  
Example of a VR experience built using the game engine Unity. (Unity, 2023)

# 03

**digital immersive applications  
for a valorization project**

At Ghesc and the Canova Association, the integration of digital innovation and historic conservation brings a new exciting chapter for visitor interaction and cultural education. For this thesis, we have developed **three projects** that help push the boundaries between traditional historical learning and exploration. With the help of digital architectural surveys, we have been able to create various projects that present many angles on Ghesc, allowing experiences ranging from **on-site immersive educational tours** to remote AR or VR interaction.

These projects aim to not only provide the Canova Association with compelling stories for marketing and fundraising, but also improve the educational experience for students actively involved in the restoration process, both on-site and virtually.



## META SPARK AR

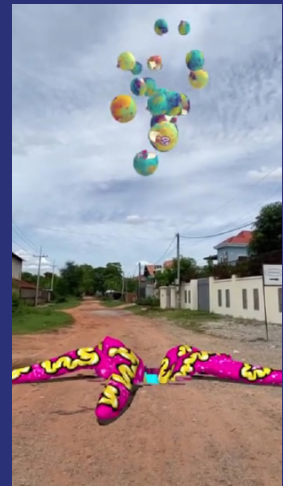
Created by the company Meta, Meta Spark AR (<https://spark.meta.com/>) is a program that lets users create augmented reality experiences and effects on well-known social networking sites like Facebook and Instagram, with ease. By integrating augmented reality, this cutting-edge tool is revolutionizing the traditional digital marketing scene and giving businesses and influencers a fresh way to reach their target audience.

Meta Spark provides an intuitive interface for developers by providing a wide variety of AR effects, such as the ability to integrate virtual models and objects on screens and recognize faces for the purpose of applying filters. It includes a testing player, a production studio, channels for distribution, and a developer community.

(Meta Spark AR, 2024)

Spark AR is easy to use, even for inexperienced developers who are just starting with app creation. Meta Spark goes beyond traditional scripting by introducing patches, which are visual code blocks that improve the understanding of effects' logic and interaction. With the help of this functionality, developers can produce AR experiences without having to know how to code. But the program's ease of use has a cost: it can only be used inside Facebook or Instagram and cannot create standalone apps for iOS or Android platforms. This limitation also places restrictions on file size, allowing only filters or experiences in extremely small file sizes.

While this tool is mainly used for marketing purposes, it can also serve as an educational tool, allowing the site to be easily visualized with just your phone. Despite file size restrictions, one of Spark AR's advantages is that it's a free platform that lets artists post an infinite number of filters. This makes it possible to publish AR filters easily and without having to create a designated app or pay monthly subscription fees to use other platforms.



**Figure 3.1**  
AR experiences built using the Meta Spark Studio.  
Top: Happy Octopus  
Bottom: Manhole Monster  
(Meta Spark, 2022)

# project 1: AR off-site

## WORKFLOW

To generate an AR experience in Spark AR, we use a three-step approach, with substeps in between. (fig 3.2)



**Figure 3.2**  
Workflow for developing AR experiences in SparkAR. (Elaboration by the authors)

## MESH OPTIMIZATION

We optimized each mesh using **Metashape**, tailoring parameters based on their original sizes and quality. Despite individual variations, we adhered to a standardized pipeline to generate lower mesh sizes with the utmost quality achievable. Having lower mesh sizes was necessary given the restrictions in Spark AR with file size.

### Metashape Workflow:

1) Resizing the **bounding box** as needed and deleting any unwanted point cloud. This will allow us to create a 3D model of only the desired space. Cleaning the point cloud first rather than later when the 3D model is created, can help create a mesh with lower sizes whilst keeping the accuracy.

2) Creating a **mesh** from the point cloud with a high quality and low face count. In some instances, when the point cloud was extremely big, we decided to create a model with medium quality, which still provided a relatively good quality model.

3) If needed, we used the tool **Close Holes** to fill in any gaps. However, this is something that needs to be double checked to avoid generating unwanted spots.

4) We use the **Decimate Tool** to decrease the model size, by decreasing the target face count. For Spark AR it is good to have a target face count of 30,000 or lower. It's important to have a good balance between model size and textures, as the latter can help enrich the model. (fig. 3.3)

5) When the 3D model was done, we generated the **textures** with a resolution of 1024 x 1024. For Spark AR, we used a range of 1 to 5 textures per model, depending on its size. The model was exported as **fbx + textures (jpg)**.



	Polygons
Original	946,726
Optimized	30,000

**Figure 3.3**  
Top: Original Model  
Middle: Optimized Model  
Bottom: Optimized Model + Textures.  
(Elaboration by the authors)

### Refining and finalizing the mesh with Blender

1) The model is imported into the 3D modeling software **Blender** (<https://www.blender.org/>) and according to the location from Metashape, we need to update the rotation, and position to make sure it's in the origin within Blender. This is to avoid issues when importing into Spark AR later.

Depending on the existing surveys and 3D meshes, sometimes we would need to combine different 3D meshes in Blender to get 1 final 3D mesh.

2) Afterward, we add a cube that covers the desired final area, and then use the **Boolean Modifier** to create the **base** of the model. (fig. 3.4) Once the base is ready, any unwanted mesh from the model can be cleaned and deleted.

3) The last step is to check the model with the **Spark Toolkit** to make sure it's ready for export. (fig. 3.5) The main issue we can encounter is the model having too many triangles, which is why the Metashape optimization step was necessary. Another problem might be the scale of the project, which can easily be solved by scaling the model down to the desired size. The model was then exported as **fbx** format.

### CREATING THE AR EXPERIENCE IN SPARK AR

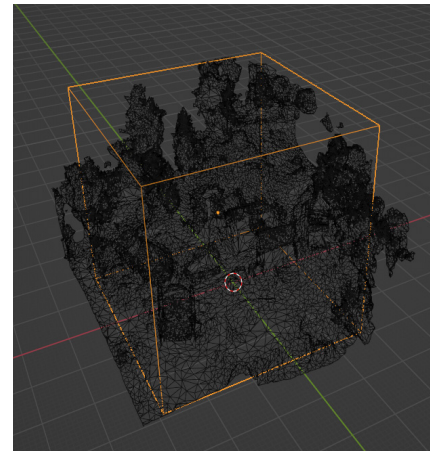
1) Meta Spark offers useful templates that eliminate the need to start projects from scratch. These templates are beneficial as they include elements such as visual codes for image tracking and plane tracking. For our different experiences, we work mainly with the templates **3D Animated Poster** that uses **Image Tracking**, and **World Object** that uses **Plane Tracking**.

2) After choosing the desired template and importing the model, SparkAR allow us to manually compress the textures if necessary and add the object into the scene.

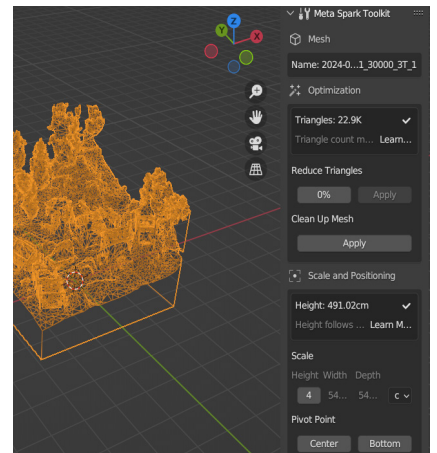
3) Depending on the needs of the final models some elements and interactive icons can be added, such as other objects, texts, and audio buttons, that we would need to setup with some visual code to make it work when touched. The audio button can help provide some educational information related to the site.

4) We can check that the file is under the required size in the **Asset Summary** and start testing the filter on our phones through the **Mobile Meta Spark Player** or the **Instagram** and **Facebook** apps. All the assets should be 6MB or less. (fig. 3.6)

5) Once the filter works as desired, it can be published for free to be used within Instagram and Facebook. A link of the filter will be provided which can then be converted into a **QR code**, to be added into postcards for easy sharing.

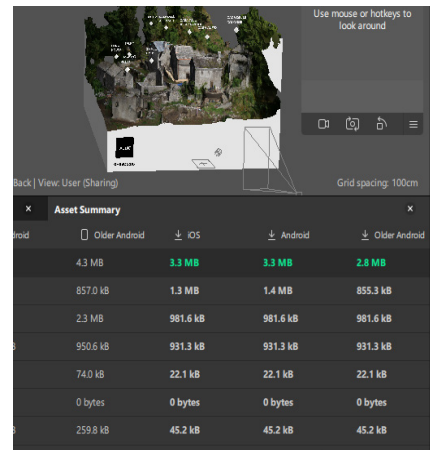


**Figure 3.4**  
Cutting the model in Blender to add the base. (Elaboration by the authors)

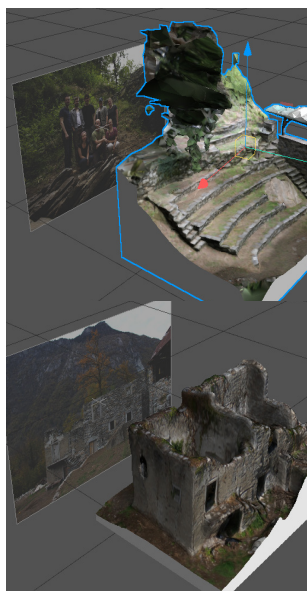


**Figure 3.5**  
Blender - Spark Toolkit to check the requirements. (Elaboration by the authors)

**Image Tracking** enables the overlaying of virtual content over an image or photo by detecting its presence. **Plane Tracking** enables the overlaying of virtual content over a surface detected such as floor or table. (Meta Spark AR, 2024)



**Figure 3.6**  
Asset summary in Spark AR to check file size. (Elaboration by the authors)



**Figures 3.7**

Top: Image of Teatro before restoration and model of Teatro after restoration.

Bottom: Image of Casa del Prete after restoration and model of Casa del Prete before restoration. (Elaboration by the authors)

## FINAL RESULTS

From the existing surveys, we were able to create 11 Spark AR experiences with plane or image tracking. (Table 3.1) (fig. 3.10 - 3.13) Plane tracking was used mainly when needed to showcase a bigger model or the whole site of Ghesc, while Image tracking was used to easily visualize individual buildings over postcards or portraits. (fig. 3.8) For the experiences with image tracking we used two distinct concepts. First, the AR model shows the building's current state, while the image shows its original structure. In contrast, the second method uses an image to show the building as it is today, while the AR model visualizes how it used to look years ago. (fig. 3.7)

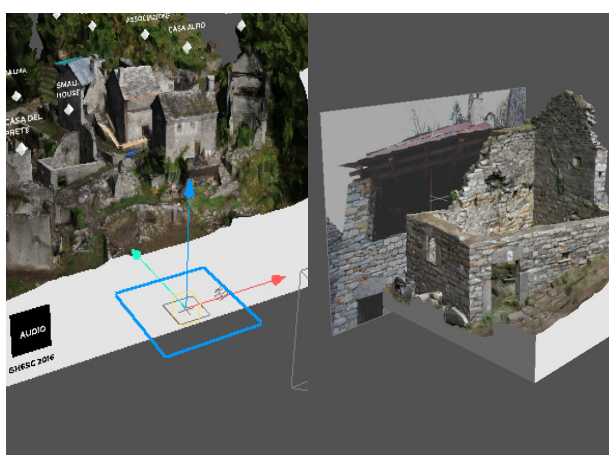
The goal of the image-tracking experiences created for Ghesc is to offer interactive, educational content that emphasizes the historical relevance of the site. Because exhibition spaces are limited, using augmented reality to overlay 3D models on photographs provides a practical way to create content without taking up a lot of physical space.

### Key Considerations

1) **File Size Restrictions:** One of the biggest restraints of creating an interactive filter with Spark AR is the file size restriction. Therefore, a good optimization workflow is necessary.

2) **Texture Quality:** The quality and detail of the textures is one of the most important elements for the visualization of the model. However, the quality of the textures will depend on how and which tools were used for the digital survey. For example this difference can be seen between the models created from the whole site survey of 2016, and the models created from the surveys of 2017 as the surveys of 2017 were created considering a lower GSD. (fig. 3.9) It's also important to notice that due to the file size restriction we were only able to create from 1 to 5 textures per model, which can also affect final visualization quality.

3) **Mesh Optimization:** There are different workflows that can be used for this process. For example, Blender can also be used for Mesh Optimization, but this workflow is more time consuming as it would need the creation of a low-poly version of the model in order to transfer the textures from the high-poly model to the low-poly version. Since metashape is a complete photogrammetric software, it allows better management of polygon models and their textures.



**Figures 3.8**

Left: Plane Tracker. Right: Image tracker (Elaboration by the authors)



**Figures 3.9**

Left: 2016 Model. Right: 2017 Model. (Elaboration by the authors)

	Tracker	# of Textures	Model Triangles	Survey
2016 Whole Site	Plane	3	20,327	2016 NEX-6
Small House	Image	1	18,108	2016 NIKON
Casa del Prete	Image	1	14,751	2016 NEX-6
Casa dell'Associazione	Plane	2	9,891	2017 CANON EOS 2017 NIKON D3100
Casa dell'Affresco & Teatro	Plane	4	13,252	2017 CANON EOS 2017 PHANTOM DJI
Half Site	Plane	2	14,258	2017 PHANTOM DJI
Entrance - Casa dell'Affresco	Image	1	4,778	2017 PHANTOM DJI
Teatro	Image	1	6,656	2017 CANON EOS
Stairs - Casa dell'Affresco	Image	1	8,932	2017 CANON EOS
Kitchen - Casa dell'Affresco	Image	1	3,566	2017 PHANTOM DJI
Info Room - Casa dell'Associazione	Image	1	15,401	2017 PHANTOM DJI

Table 3.1  
Characteristics of each Spark AR experience created.

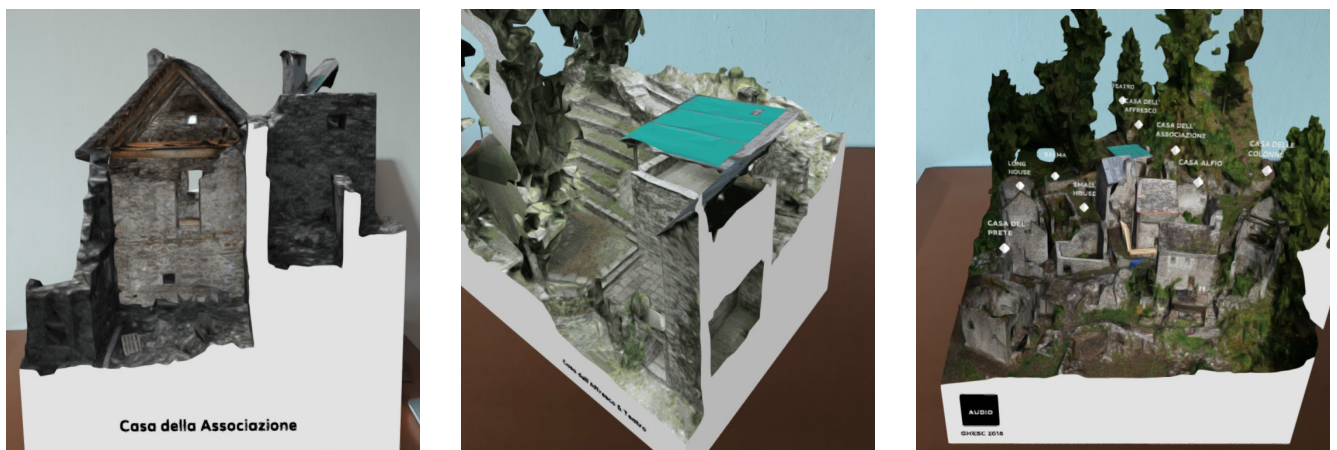


Figure 3.10  
Casa dell' Associazione (left); Casa dell' Affresco & Teatro (middle); 2016 Whole Site (left). (Elaboration by the authors)



Figure 3.11  
Half Site (left); Info Room - Casa dell' Associazione (middle); Small House (right). (Elaboration by the authors)



Figure 3.12  
Casa del Prete (left); Kitchen - Casa dell' Affresco (middle); Teatro (right). (Elaboration by the authors)

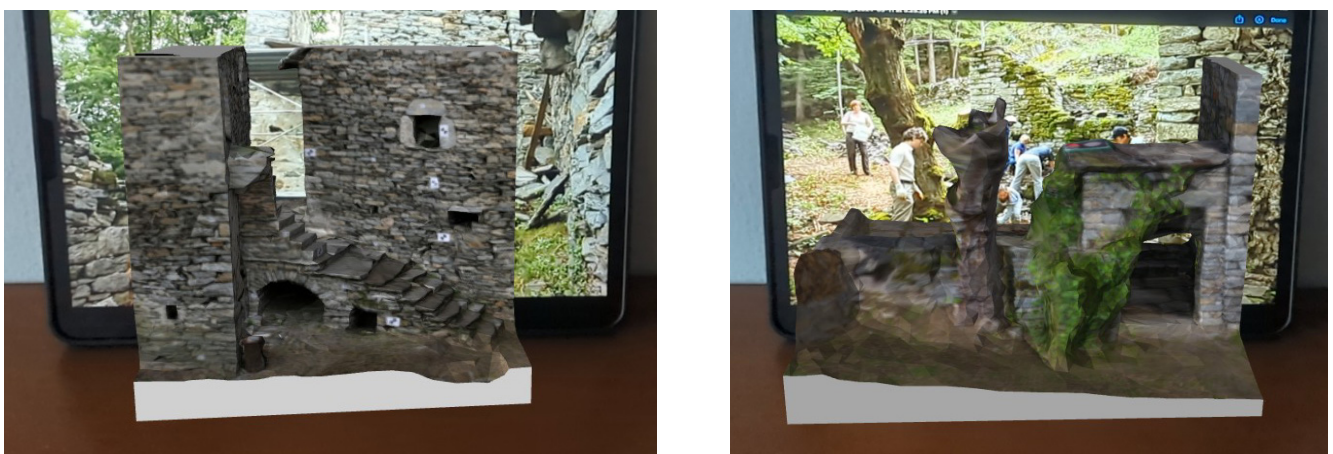


Figure 3.13  
Stairs - Casa dell' Affresco (left); Entrance - Casa dell' Affresco (right). (Elaboration by the authors)

## IMMERSAL SDK

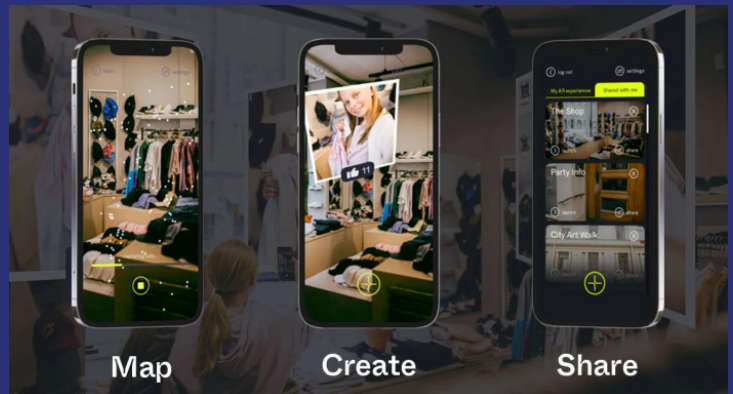
The Immersal SDK is a spatial mapping and visual positioning system (VPS), a technology that compares the images taken by the device's camera to a database of pre-mapped photos. By using computer vision and machine learning algorithms, it predicts the device's location and orientation, based on similarities and differences between the acquired images and the pre-mapped ones. It enables devices to precisely locate themselves in the physical world, making it possible to blend digital content with the real world. It can be thought of as a highly accurate GPS with **six degrees of freedom** and **real-time updates**. The device not only knows its location in the world but also its exact orientation. As this is a fully **marker-less solution**, there is no need to print QR codes or any kind of target image. The environment itself is used as a marker.

With Immersal it's possible to develop AR experiences that are linked to real-world locations, enabling users to interact with their surroundings and perform things that would be otherwise impossible. Immersal's technology is made up of three main parts:

1. **Real-world mapping:** the maps are recorded using the Immersal Mapper app, and then can be built and hosted on Immersal's Cloud Service. In our case, we directly used Leica's BLK2GO for mapping, a fairly recent technology. Despite the Immersal Mapper's convenience and flexibility of allowing the scans to be done with a smartphone, the BLK2GO's laser scans ensure greater accuracy of the survey.
2. **Building applications:** using the maps and the Immersal SDK, extensive, detailed documentation and guides on how to set up the project, making the process easy to follow.
3. **Localizing:** finding the position and orientation of the user's device to present the digital AR content

Immersal SDK is tool that brings immersive AR experiences to life. Its applications are endless, ranging from AR games and ad campaigns to navigation and education - the sky is the limit. (Immersal, 2023)

**Software Development Kit (SDK)** is a collection of tools, libraries, code samples, manuals, that enable developers to create software applications for a certain platform. SDKs help to avoid repetition of code by generating common code that can be reused.



**Figure 3.14**

"The Immersal App is a totally new and simple way to create, share and experience life in the metaverse. Use it to map a real-life space on your phone or tablet, add digital content like pics, videos, emojis and messages, and share with whoever you want." (Immersal, 2023)

# project 2: AR on-site

## WORKFLOW

As mentioned on the “Ghesc Survey” chapter, Immersal provides a **Developer Portal** where the developers can register for a free account to gain access to Immersal’s services and resources. From the website, four maps with different extensions can be downloaded:

- .bytes: a map file used by the SDK for localization
- .ply: representations of the actual map
  - a sparse point cloud
  - a dense triangle mesh
- .glb: a textured triangle mesh representation of the map

The latest **Immersal SDK Core package** can also be downloaded from the portal, and a link directs to Immersal’s GitHub repository, to download the latest sample project. These are the files that will be imported into the game engine **Unity** (<https://unity.com/>) in order to build the AR application. (Immersal, 2023)

### Unity project set up

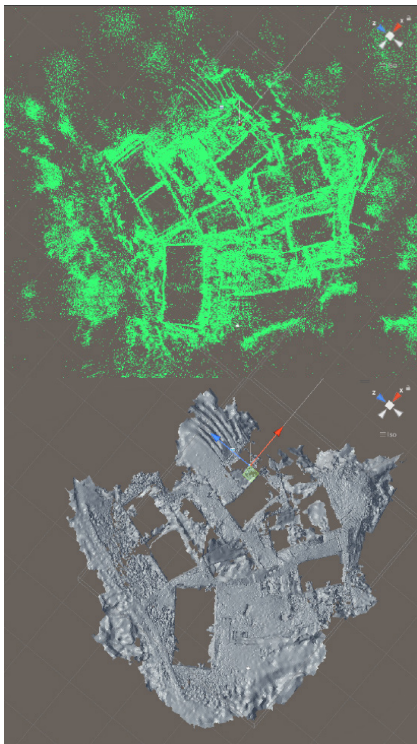
1) After importing the Immersal’s sample project into **Unity** and adding the Immersal SDK’s package, both the **sparse point cloud** and the **dense mesh triangle** can be inserted into the project (fig 3.15) so that they can be visualized<sup>1</sup>. We also have to upload the **map file** as it is what will set off the localizing system, recognizing the location and placing the AR content according to it. This map can be utilized for offline, on-device localization, and so, just as it would with any Unity project, the AR content can be placed and the logic of the experience can be configured for the desired effect, which then can be built for the chosen platform.

2) The desired platform for which the app will be built must be selected, which in our case is **Android**, since all available hardware to create this project is from the Android ecosystem.

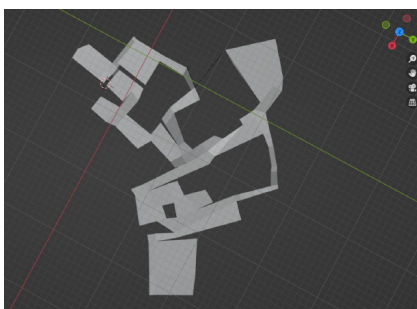
The sample project consists of various sample scenes, each with different functions, for different use cases. For this project, the scene that will be used is the **Navigation Sample**, which features a simple navigation system that allows the user to choose a target location, and the system will guide them to it using virtual arrows. (fig. 3.22) To be able to implement this system, a **Navigation Mesh** (NavMesh) needs to be created. This mesh can be made in a third-party modeling software, in this case, Blender. (Immersal, 2023)

### Building the floor geometry on Blender

3) Opening **Blender**, the sparse point cloud can be imported as a base for modeling. Since the site is large and has a lot of wild vegetation, for easier visualization it is best to use the dense mesh instead. After cleaning the vegetation and some of the noise<sup>2</sup>, the mesh can be now used as a reference to build the navigation geometry. It essentially consists of a geometric representation made of planes, shaped and attached to each other, to match the desired real-world floor area. Since this app is intended to be a tour through Ghesc, the NavMesh will only pass through the main pathways around the houses and any path where the user can walk on. Once the basic floor geometry is done (fig. 3.16), it should be exported as a **.fbx** file, with the exporting settings adapted to Unity’s coordinate



**Figure 3.15**  
Sparse point cloud (top) and dense triangle mesh (bottom) after being imported into Unity. (Elaboration by the authors)



**Figure 3.16**  
Floor geometry built in Blender. (Elaboration by the authors)

<sup>1</sup>These are not actual Leica scans; they are visual positioning maps, which means they are used primarily as a visual reference for placing the digital content.

<sup>2</sup>Noise: random points picked up by the laser scanner that are not important to the definition of the map.

system.

### Setting up navigation in Unity

4) Back in Unity, after importing the floor geometry, it should align with the point cloud preview of the downloaded map. Then its default layer has to be changed to a Navigation layer. The SDK provides a **Generate NavMeshSurface Here** script, which will include any geometry in the Navigation layer for baking. After baking the mesh, the NavMeshSurface data should be visible (fig. 3.17), overlaid on top of the floor geometry with a blue color, confirming that the navigation system is all setup. To take advantage of this system, the SDK provides **Navigation Targets** (fig. 3.18), a simple game object scripted to be selected by the user to guide them to the location where the target was placed<sup>1</sup>. (Immersal, 2023)

### Placing AR content

5) After following all the steps above, it is time to start adding the AR content that the user will see on their device. At this point, anything can be used, as long as is properly set up. For this project, the navigation targets will be placed in strategic locations of Ghesc. The chosen points of interest are the eight houses of the village, or more specifically any place that has undergone a transformation during the school camps, which the Canova Association carefully recorded in a photographic catalogue of the activities.

6) When the user arrives at these points, in front of the navigation targets will be an AR panel with a hand drawing of the respective house and two buttons: “About” and “Models”. (fig. 3.18)

When clicking on the **ABOUT** button, a window will pop up playing an audio file reading the content on this window: the name of the house and a small description of it. Underneath this text there is a collection of photographs of the renovations done on the buildings. (fig. 3.20)

7) Besides these virtual guides, each location will also feature 3D models, corresponding with the meshes created from the point clouds that were surveyed in 2012, 2016 or 2017. After closing the house page and clicking on the **MODELS** button, a small panel will appear with buttons to the models of the year available, one with a simple solid color (fig. 3.23) - for an easier volumetric visualization of the transformations - and another with its original textures (fig. 3.24) - for a more accurate representation of how it used to look in that year. Both of them were carefully positioned in order to overlay the real building, so that the user can have a clear comparison of the transformations that have taken place there.

## BUILDING AND TESTING

Once the project is finished, the application can be built and launched to the smartphone. When opening the app and looking around the site, the device will attempt to find the poses. Since Immersal uses VPS, this means that when the device’s camera points at a location that was mapped, it should be able to analyse those images and find a match - as shown in the image, the green points match with the structure of

**Navigation Mesh** (NavMesh) is a component of Unity’s built-in navigation system that allows game objects, usually characters, to navigate in the game environment intelligently. NavMeshes are used to define the floor surfaces and paths that are walkable within the game, allowing the characters to find the shortest path between two points, move around obstacles, and avoid collisions. (Immersal, 2023)



**Figure 3.17**

After importing the floor geometry into Unity, the NavMesh (in blue) was baked. (Elaboration by the authors)



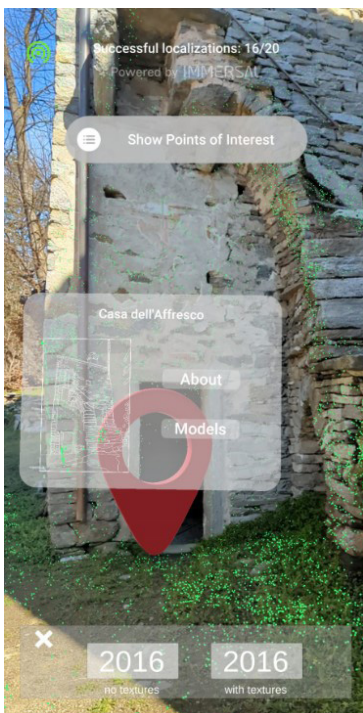
**Figure 3.18**

Navigation Target (red) provided by Immersal SDK, personalized with an AR panel for further information about each house. (Elaboration by the authors)

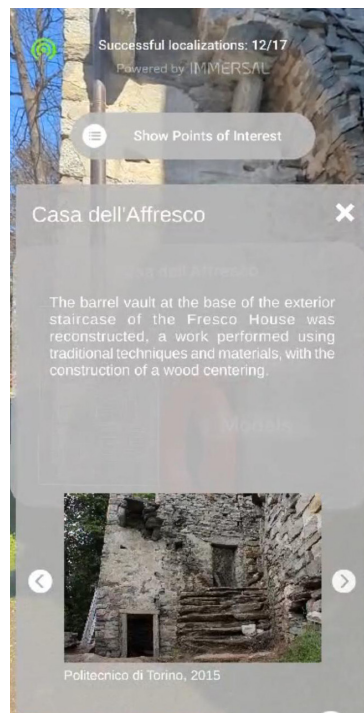
<sup>1</sup>Once the user selects a target, the navigation system will try to find it, only if it’s reachable. If a target is outside of the boundaries of the NavMesh surface or is too high, a message saying that the target cannot be found will appear on the device.

the building. (fig. 3.19) After successfully localizing, all created digital content should align with the real world, and then the immersive AR tour can finally begin.

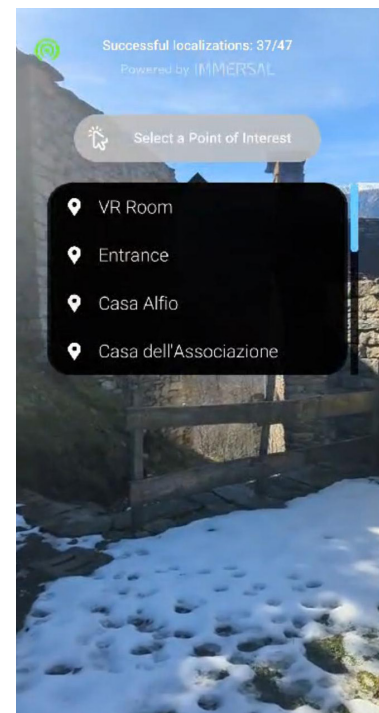
## FINAL RESULTS



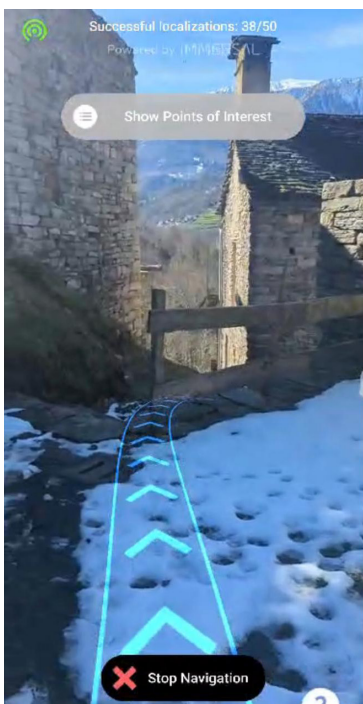
**Figure 3.19**  
After the map (green points) finds the poses, it overlays the AR content with the real-world. (Smartphone Screenshot) (Elaboration by the authors)



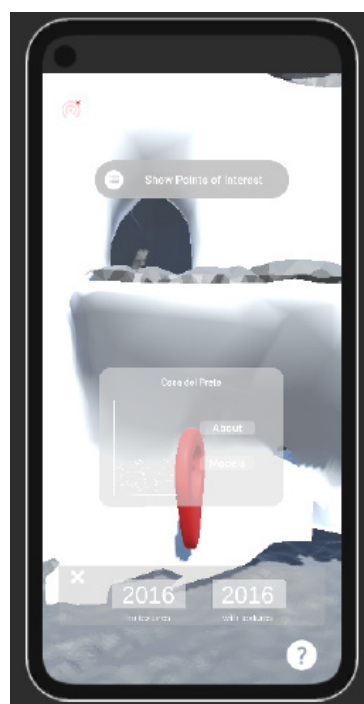
**Figure 3.20**  
After clicking on ABOUT, a page appears with the name and description of the house, and photos of the renovations. (Smartphone Screenshot) (Elaboration by the authors)



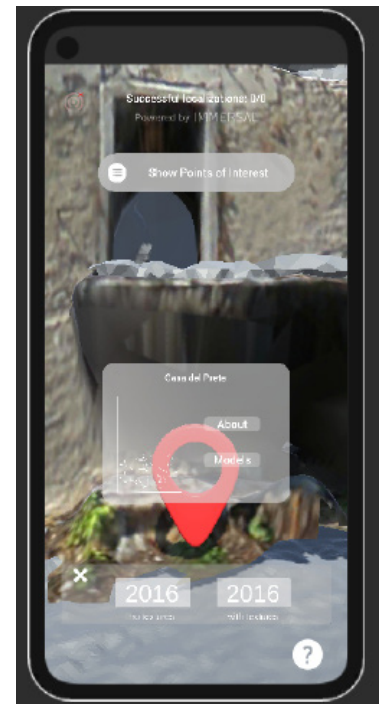
**Figure 3.21**  
Navigation menu with all of the targets. (Smartphone Screenshot) (Elaboration by the authors)



**Figure 3.22**  
After selecting the destination, the navigation system will lead us there. (Smartphone Screenshot) (Elaboration by the authors)



**Figure 3.23**  
Volumetric model of Casa del Prete on the year 2016 in white. (Smartphone Screenshot) (Elaboration by the authors)



**Figure 3.24**  
Model of Casa del Prete on the year 2016 with its original textures. (Smartphone Screenshot) (Elaboration by the authors)

**Figure 3.25**  
Site plan of Ghesc  
Scale 1: 250  
(Elaboration by the authors)



## Houses Descriptions

### **Point 1: Village Entrance**

Welcome to Ghesc, the Laboratory Village.

Years ago, Ghesc was nothing but a small abandoned settlement in the Piedmont mountains. Today, thanks to a rehabilitation initiative led by the Canova Association with the help of students from all over the world, this medieval village is being restored to its former glory.

### **Point 2: Casa Alfio**

Back in 2007, two members of the association - Maurizio Cesprini and Paola Gardin - decided to buy and restore one of the houses in Ghesc, focusing on improving what was already there and using sustainable materials. Casa Alfio was later recognized at the prestigious International Prize for Sustainable Construction in the Alps in 2015. They decided to move there, and are now the only inhabitants currently living in Ghesc.

### **Point 3: Small House**

The Small House does not belong to the Canova Association but to Professor Bocco of the University of Turin, which shows that some private individuals also share the same ideas and spirit of the association.

### **Point 4: Casa del Prete**

The remaining five properties are planned for individual dwellings, with two currently undergoing restoration.

### **Point 5: Casa dell'Associazione**

The Canova Association has acquired a small set of buildings to provide practical didactic projects and activities for workshops and field camps. In this project of the village laboratory of Ghesc, the buildings owned by the association are intended to be used as an ongoing educational site where contemporary housing needs are combined with the use of traditional techniques and materials.

### **Point 6: Casa dell'Affresco**

The barrel vault at the base of the exterior staircase of the Fresco House was reconstructed, a work performed using traditional techniques and materials, with the construction of a wood centering.

### **Point 7: Balma and Long House**

The Canova Association's initiative is a constant work in progress and transformation of this small village, due to the contributions of each participating field school. Building recovery and reuse projects are based on ideas shared by the participants, utilizing stone, rubble, and other materials saved from the original buildings, with the goal of preserving these centuries-old traditional techniques.

### **Point 8: Teatro**

Previously overrun by vegetation, this area was transformed into a new outdoor space: an amphitheatre consisting of several rows of dry-stone steps, followed later by the expansion of this area with the construction of new bleachers and a staircase.

**Figure 3.25**  
Site plan of Ghesc  
Scale 1: 250  
(Elaboration by the authors)



**Point 9: Terrace of Casa dell’Affresco**

At the terrace of the Fresco House, they implemented a stone slab paving above a vaulted space, while on the first floor, a new refractory brick and stone kiln was built. A year later a chimney and chimney pot above the furnace were added. Both the Terrace and the Teatro occasionally house educational initiatives and cultural events.

**Point 10: Kitchen of Casa dell’Affresco**

Construction of a kitchen in the Fresco House, as well as a second portion of the staircase between the Association and the Fresco Houses.

**Point 11: Room of Casa dell’Associazione**

*No activity in progress.*

**Point 12: VR Room**

The room in the basement of the Fresco House will be converted into the final part of the tour, which showcases the village through the years of its many restorations.



# project 3: VR on/off site

## MESH OPTIMIZATION

1) The mesh optimization workflow used for VR is similar to the workflow used for Spark AR. The only difference lays on the step 4 and 5. As Unity is not restricted by the limitations of Spark AR, since there is no need for a drastic decrease of file or texture size. In turn, it's important to find a balance between having a detailed mesh model and high-quality textures. For VR, around 20 to 50 textures with 4K resolutions were created per model. (Table 3.2)

	# of Textures	Model Triangles	Survey
2016	40	888,537	2016 NEX-6
2017	85	1,811,058	2017 CANON EOS 2017 NIKON D3100 2017 PHANTOM DJI

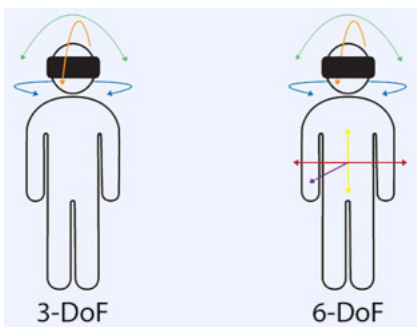
**Table 3.2**  
Characteristics of VR models.

## WORKFLOW

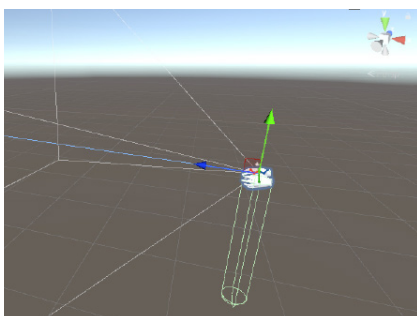
### Creating a new project in Unity

2) Once Unity Hub is open, a **New Project** can be created using the vast list of templates provided by Unity. For this project specifically, the **VR Template** can be used as the baseline for the VR experience, as it already contain multiple components and functions that will be

**XR Interaction Toolkit** is an interaction system for creating VR and AR experiences, that provides different elements and scripts that enable the user to interact with the 3D and UI elements. (Unity, 2023)



**Figure 3.26**  
“Difference between 3-DoF (rotational movement) and 6-DoF (rotational and translational movement) with a VR headset.” (Barnard, 2023)



**Figure 3.27**  
XR Rig with main camera and hand controllers. (Elaboration by the authors)

used throughout this project.

After launching the project, the first step to take is to install the **XR Interaction Toolkit**, the package which allows the developer the access to a wide range of interactable components, making it possible to create a entire VR experience from beginning to end.

### XR Rig

2) Once the package is installed, we can start creating the actual experience. The first thing needed is an **XR Rig**, which is essentially the user's eyes, ears, and hands in the virtual world. Together with a Locomotion System - a component that will be explained in detail further ahead - it allows the user to move around in the environment. There are two types of XR Rigs: Stationary and Room-Scale. A **Stationary XR Rig** uses the headset as the tracking origin, allowing only three degrees of freedom (fig. 3.26), a great option for experiences where the user remains seated or standing in one position. The **Room-Scale XR Rig** uses the floor where the user is physically located as the tracking origin, allowing for six degrees of freedom - rotational and positional movements (fig. 3.26) - shaping the virtual world at the scale of the real world. It can be used for projects where the user walks around in the virtual environment. Unlike the Stationary Rig - compatible with all devices capable of supporting XR - the Room-Scale Rig requires a headset capable of mapping the user's environment and their movements within it. As this experience is designed to visualize and explore the hamlet of

Ghesc, the best option for this project is the Stationary Rig.

The XR Rig (fig. 3.27) contains the **Main Camera**, the user's eyes, and both the **Left** and **Right Controllers**, the user's hands. Basically, these two components virtually represent the user in the digital world, enabling them to interact with it.

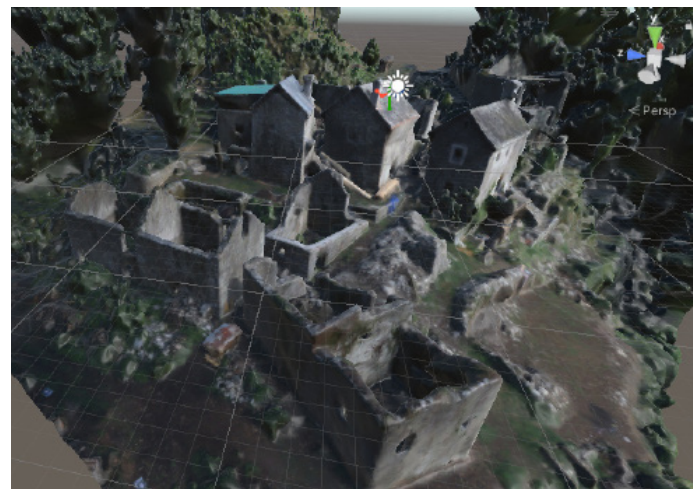
3) The next step is to add a **Locomotion System** that will provide the means for the XR Rig to move around the scene. For the user to actually be able to move, two components need to be added to the system: a **Continuous Move Provider** and a **Continuous Turn Provider**. As their names suggest, these allow the XR Rig to move forward and backward (even sideways if desired), and to rotate 360° around its own vertical axis. Both components need a reference to the controller's buttons that will generate these movements, typically being - and also in this project - the controllers' joysticks - left for moving and right for rotating.

**Locomotion System** is used to control the access to the XR Rig. It makes it so that it is the only system that controls the movement of the XR Rig - the user. (Unity, 2023)

4) As mentioned above, the XR Rig directly comes with the controller's components, allowing them to work as the user's hands. These come in a form of 3D models of hands, and Unity provides different animations to follow basic hand motions, associated to distinct functions, from grabbing objects, to selecting and clicking on buttons. For simplicity of the experience for users who are not familiar with how VR normally works, the only function that was kept was the **Ray Interactor**, essentially a laser beam that comes out of the controllers to point and click at objects and buttons. (Unity, 2023)

### Environment

5) The virtual environment of this experience is Ghesc itself, made up of three different 3D models built from the point clouds created based on the data collected in the three different years - 2012, 2016 and 2017. After being converted into a textured mesh, the models were each imported into the Unity project and aligned with each other according to the current reference system. The model from 2016 is being used as the default environment as soon as the user begins the experience, as it is the most recent and the most complete model out of the three. (fig. 3.28)



**Figure 3.28**  
2016 model - default model when the experience starts. (Elaboration by the authors)

6) For it to be possible to walk around the models, a 'floor' is necessary. This can range from a 2D plane to a 3D volume, as long as it consists of some sort of boundary that the user cannot go through, or, in this case, fall through, as Unity follows the laws of physics and gravity. There are two main options to achieve this: either by building a floor model 'by hand', or by assigning a **Mesh Collider** component to the actual 3D models. Both alternatives can be used for this project, but they are done using different methods and can be applied for different reasons.

**Mesh Collider** is a component that builds a collider that matches the geometry of the Mesh Asset it is assigned to. It allows the player - in this case, the user - to detect a collider in an object and not be able to go through it, making it essentially a rigid body, similar to how people cannot go through physical objects - like walls. (Unity, 2023)

6.1) The **floor model** can be built using a third-

party software, in this case Blender, to create a floor using 2D planes that follow the geometry of the floor and the walls of the 3D model. After building it and exporting it to Unity, it essentially creates a labyrinth-like model that forces the user to follow the designed pathway. This is good for experiences similar to a guided tour, where we want the user to follow a specific route, from beginning to end. Lastly, the floor should be 'hidden' by changing its properties to not be rendered once the app is built, so that the user won't be able to actually see this model.

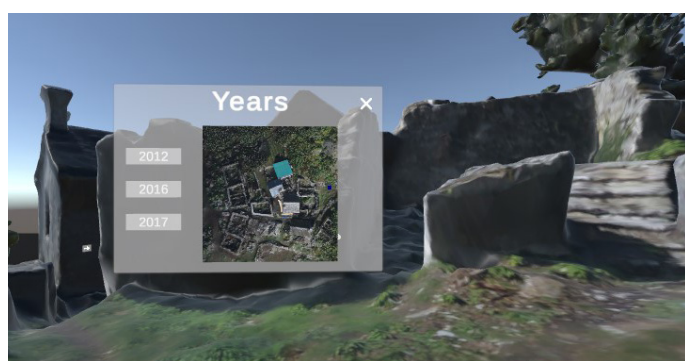
6.2) The second method is by assigning a **Mesh Collider** component directly to the 3D models, in Unity. Despite being having mesh textures, when imported to Unity, the models are still that - 3D digital models. To work as a 'physical' environment, that follows the laws of physics, they need to have the physical properties of real, tangible materials. Otherwise, when the user comes across them, they will be able to go through them. In the case of it being a horizontal floor, the user will fall down, infinitely, as if stranded across outer space. With a Mesh Collider, the model's floor will work as a real-world floor, so people cannot go through it - the same for the walls. This approach gives the user total freedom to walk around the entire environment - until its boundaries, of course - allowing for a wider reach. They will be able to go through doors, or any kind of openings, go inside buildings, all around the entire village. Of course, this can also be the case when building the floor model from scratch, but that requires an initial decision and designing of all the areas that are to be accessible. Therefore, the Mesh Collider component is a faster, more efficient alternative that can solve the problem 'with the click of a button'. (Unity, 2023)

### User Interface

7) With the help of a **User Interface** in the form of a 'Game Menu', with the click of a button on the controller, previously scripted and assigned, the user can access a **UI Menu** (fig. 3.29) where three different buttons can switch the environment between the three models, transporting

**User Interfaces** (UI) are the access point with which the user can interact with a design. These can be Graphical, if the user interacts with a visual representation - for example, a computer's desktop is a form of GUI; Voice-controlled, if the user can interact by using their voice, such as smart assistants like Siri, Alexa, etc; or Gesture-based, when a user can engage with a virtual space through their own body movement, which is the case of most VR games. (IxDF, 2016)

the user to 2012, 2016, and 2017, allowing them to explore Ghesc and discover the transformations that have taken place there throughout all those years. To be able to click on these buttons, the user can take advantage of the Ray Interactor mentioned before, assigned to the hand controller, to point and click on the buttons.



**Figure 3.29**  
UI Menu with button to switch the environment to a different year.  
(Elaboration by the authors)

8) As the user walks around the village, they will also come across digital posters identifying each house, with a hand drawing representing the specific building, and a small text describing it, and the renovations that have taken place there. (fig. 3. 31)

## TESTING AND PUBLISHING

After many trials and rectifications, the project can finally be launched to the platform of choice, in this case, as an application for the **Oculus Quest**. Even though Unity's XR Interaction Toolkit allows for multi-platform development, since the hardware available was the Oculus

headset and controllers, the Unity project was already set up with the specific requirements of this device, so the app was built and launched directly to its platform.

## FINAL RESULTS



**Figure 3.30**  
2016 model - default model when the experience starts. (Elaboration by the authors)



**Figure 3.31**  
After clicking in an info button, a panel will appear describing the house and the renovations it went through. (Elaboration by the authors)



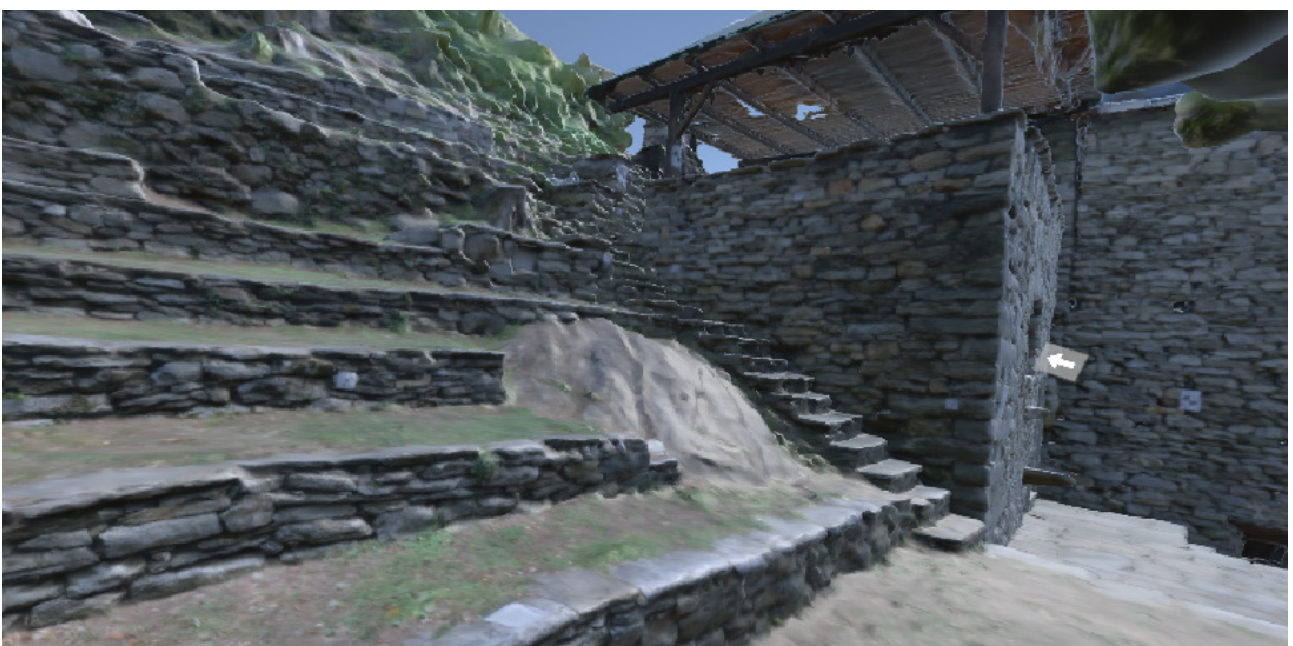
**Figure 3.32**  
After clicking on the 2017 button of the UI Menu, the environment changes to the 2017 model. (Elaboration by the authors)



**Figure 3.33**  
Casa dell'Affresco (left) and Casa dell'Associazione (right) in 2017. (Elaboration by the authors)



**Figure 3.34**  
Casa dell'Affresco, looking from the Balma House. (Elaboration by the authors)



**Figure 3.35**  
Teatro (left) and Casa dell'Affresco (right) in 2017. (Elaboration by the authors)



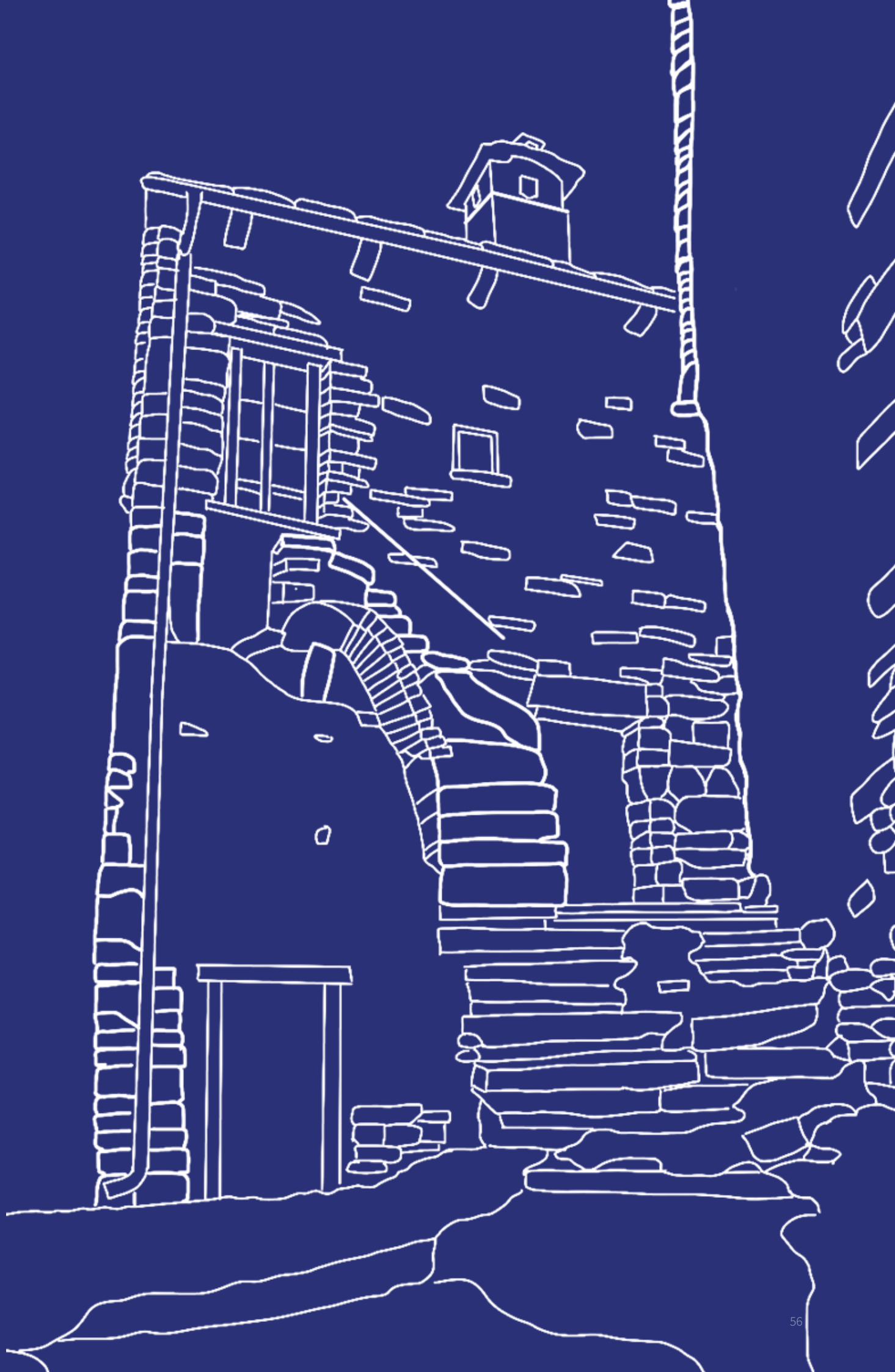
**Figure 3.36**  
Terrace of the Casa dell'Affresco in 2017. (Elaboration by the authors)



**Figure 3.37**  
Room inside of the Casa dell'Associazione in 2017. (Elaboration by the authors)

# 04

**d i s c u s s i o n**



	<b>META SPARK AR</b>	<b>IMMERSAL</b>	<b>VIRTUAL REALITY</b>
<b>Devices Used</b>	Smartphone with iOS or Android operating systems	Smartphone with Android operating systems	Meta Quest – Oculus Quest 1
<b>Main Use</b>	Marketing & Educational	Marketing & Educational	Marketing, Educational & Digital Conservation
<b>Survey Method</b>	Laser Scanner Aerial and Terrestrial Photogrammetry	BLK2GO (handheld laser scanner)	Laser Scanner Aerial and Terrestrial Photogrammetry
<b>Location</b>	On site or remotely	On site	On site or remotely
<b>Pipeline</b>	Metashape Blender Spark AR	Blender Unity	Metashape Blender Unity
<b>Knowledge Needed</b>	Basic knowledge of all the pipeline programs.	Basic knowledge of all the pipeline programs.	Basic knowledge of all the pipeline programs. Basic knowledge of coding in C#.

Table 4.1

Overview of the projects, by analyzing and comparing their main characteristics.

# projects overview

This thesis explores the use of different digital applications such as AR and VR for architectural visualization. These projects were developed using a variety of technological tools, approaches, and devices. One of the benefits of Spark AR and Immersal is that these experiences can be accessed via smartphones, making them more accessible and allowing a broader audience to engage with these AR content. However, to guarantee effective operation, Immersal needs a smartphone with sufficient storage. On the other hand, the VR project requires the use of a VR Headset with hand controllers, which is a more specialized yet immersive implementation.

Every project is similar to the others in the sense that it serves both marketing and instructional objectives, with VR being able to also serve for digital preservation as it can provide a more detailed visualization. This multifunctionality fills in the gaps between informing and educating audiences, remote or in person, and promoting Ghesc and the Canova Association. Moreover, Immersal needs the user's physical presence on site to provide an interactive tour of Ghesc's surroundings, whereas Spark AR and VR offer more flexibility as it can be accessed on-site or remotely.

The length and complexity of mesh optimization varies according to the specific goals and needs of each project. For example, the VR experience requires additional time as the models need to have better quality and texture details for an enhanced user experience.

This comparative analysis highlights the technological details and needs for their effective application. (Table 4.1)

## FUTURE CONSIDERATIONS

	META SPARK AR	IMMERSAL	VIRTUAL REALITY
Devices Required	Smartphone with iOS or Android operating systems	Smartphone with iOS or Android operating systems	Meta Quest (Oculus) OpenXR Windows Mixed Reality etc
Possible Uses	Marketing & Educational	Marketing & Educational	Marketing, Educational & Preservation
Best Survey Method	Aerial Photogrammetry	BLK2GO	Terrestrial Photogrammetry
Time for data collection	Less that a day depending on the size of site.	A few hours depending on the size of site.	Several days depending on the size of the site.
Mesh Optimization	Needed	Not Needed (models can be used as extra elements)	Need
Best Pipeline	Metashape Blender Spark AR	Blender Unity	Metashape Blender Unity
Pipeline Time	Within a day only 1 experience.  Aprox. 70% Metashape 20% Blender 10% SparkAR	Within a day.  Aprox. 5% Blender 95% Unity	A few days.  Aprox. 15% Metashape 15% Blender 70% Unity
Publishing	Free	Apple Store and Play Store subscriptions	Free

**Table 4.2**

Future considerations to take in mind for someone who wishes to recreate these projects.

The benefits of using Spark AR for future AR projects lay not only in their accessibility but also in the fact that their development and distribution can be done with open-source software such as Blender and Spark AR. Although it's possible to create a custom AR application to avoid the limitations of Spark AR, this would require more advanced programming skills, a larger workload, and a budget availability to pay for the app publishing fees on the different platforms. Therefore, Spark AR can be the best option for organizations who have a tight budget and need a fast workaround.

Creating realistic digital replicas required an effective digital survey. Aerial photogrammetry is the best survey method for Spark AR as it offers a speed-quality balance. This approach can quickly produce medium to high-quality models. Considering Spark AR's restrictions regarding file size, ultra-high-quality models are not necessary as the platform may not be able to handle them completely. In addition, for VR, terrestrial photogrammetry is preferred as it can provide high-detail models which are required for an immersive experience. However, both methods can be combined to maximize each of their advantages. On the other hand, as Immersal does not need the data to provide color and texture details, the use of the BLK2GO handheld laser scanner is needed.

The different projects pipelines and timeframe are another important element to consider for the creation of future digital experiences, with Spark AR and Immersal being the fastest methods with a low learning curve, while VR would require extra time and basic knowledge of C# language.

For mesh optimization it is important to consider that we used a paid software such as Metashape, however, this could also be achieved by using a different free software. Depending on the software or technique used, the timeframe for mesh optimization could be longer.

As previously stated, publishing the experience on Spark AR is free, which is also true for publishing a VR experience. However, for Immersal, we need to consider fees for software services like Immersal's initial survey generation, and publishing fees as the final output would be a custom Android or iOS app. (Table 4.2)

# 05

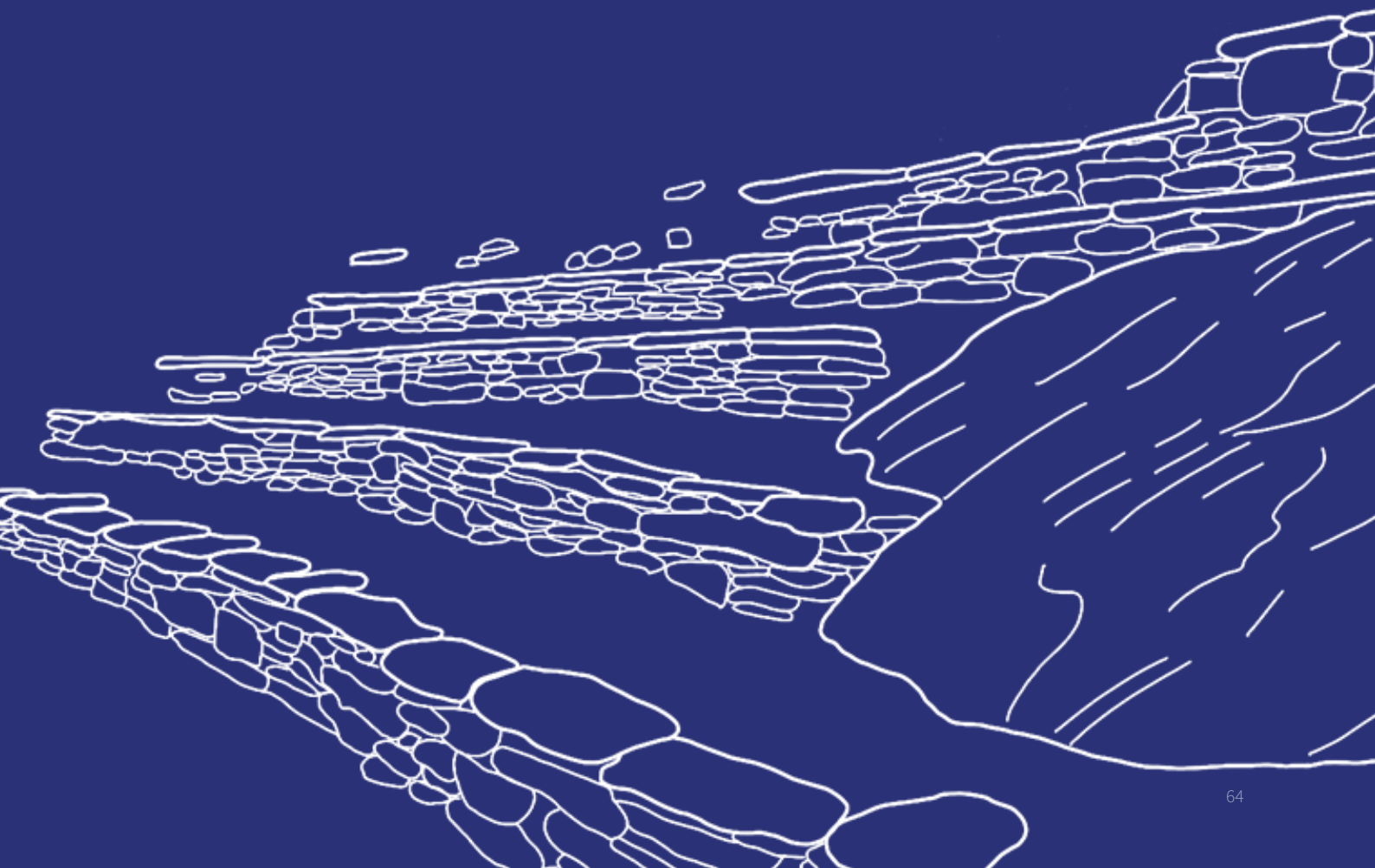
conclusion

In conclusion, this thesis has demonstrated the role of **Augmented Reality (AR)** and **Virtual Reality (VR)** as innovative tools for valorization of heritage sites. The three projects developed for Ghesc have not only shown the potential for AR and VR in **digital preservation**, but also how these technologies can enhance user's interactions and experience with the site.

As these projects were created with the needs of the **Canova Association** in mind, they are not meant to stand alone, but to work in tandem with one another, each with a distinct function and varying degrees of user involvement. They are useful and innovative tools that can help fulfill the association's funding-gathering and heritage conservation promotion goals by addressing the objectives of marketing, education, and—above all—digital heritage preservation of Ghesc's legacy. The goal of the **Spark AR** project is to make Ghesc's history easily accessible by making it available to a larger audience. The **Immersal SDK** initiative enhances visitors' on-site experiences by integrating narrative and information directly into Ghesc's physical location. For distant users, **Unity VR** provides an immersive experience with comprehensive educational content that emphasizes the historical relevance of Ghesc.

The future of digital preservation will change as digital technologies will keep evolving throughout the years. As this discipline develops, so should our approaches to record and preserve heritage architecture. In addition to serving as a model for marketing historical sites like Ghesc, the use of AR and VR technologies can also provide a strategy for future efforts aimed to **preserve** and **valorize** our **cultural heritage** in an increasingly digital era.

## **reference material**



Achille, C., Fassi, F., Mandelli, A., Fiorillo, F., 2018. Surveying cultural heritage: summer school for conservation activities. *Applied Geomatics*, 10, 579-592. doi.org/10.1007/s12518-018 0225-3.

Angeloni, E., 2022. Ghesc: così uno dei borghi più belli (e anti chi) del Piemonte è tornato a vivere grazie agli studenti. *GreenMe*. [online] Available at: <https://www.greenme.it/ambiente/buone-pratiche-e-case-history/ghesc-uno-borghi-piu-belli-piemontese-tornato-vivere-grazie-studenti/> (Accessed: 10 October 2023)

Aziz, K. Ab., & Siang, T. G., 2014. Virtual reality and augmented reality combination as a holistic application for heritage preservation in the UNESCO world heritage site of Melaka. *International Journal of Social Science and Humanity*, 4(5), 333–338. doi:10.7763/ijssh.2014.v4.374

Belardi, P., & Menchetelli, V., 2018. 4DGypsoteca. Un'architettura multimediale per la didattica del disegno. In A. Luigini & C. Pancioli (Eds.), *Ambienti digitali per l'educazione all'arte e al patrimonio* (pp. 35-50). Milano, IT: FrancoAngeli.

Bolognesi, C. M., & Fiorillo, F., 2019. The integration of 3D survey technologies for an accurate reality-based representation. *Conservation, Restoration, and Analysis of Architectural and Archaeological Heritage*, 321–345. <https://doi.org/10.4018/978-1-5225-7555-9.ch013>

Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., Ivkovic, M., 2010. Augmented reality technologies, systems and applications. 342-348.

Cesprini, M., 2015. The Workshop Village of Ghesc, A Village for Learning. *Associazione Canova*, 1-6

Cesprini, M., Marquardt, K. 2020. The Canova Association: "Historical Continuation" and the Rebirth of Two Northern Italian Villages. *Journal of Traditional Building, Architecture and Urbanism*, (1), 271-276.

Comunità Montagna, 2023. Una storia di riqualificazione: Ghesc (Verbano-Cusio-Ossola). *Comunità Montagna*. [online] Available at: <https://www.comunitamontagna.eu/territori/una-storia-di-riqualificazione-ghesc-verbano-cusio-ossola/> (Accessed on: 20 October 2023)

Facchi, E., Grimoldi, A., & Landi, A. G., 2022. Vernacular architecture and written sources: The case study of the tronto valley. *Proceedings HERITAGE 2022 - International Conference on Vernacular Heritage: Culture, People and Sustainability*. doi:10.4995/heritage2022.2022.14321

Fassi, F., & Campanella, C., 2017. From Daguerreotypes to Digital Automatic Photogrammetry. Applications and Limits for the Built Heritage Project. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-5/W1, 313-319.

# bibliography

Fassi, F., Fregonese, L., Ackermann, S., and De Troia, V., 2013. Comparison between laser scanning and automated 3d modelling techniques to reconstruct complex and extensive cultural heritage areas, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XL-5/W1, 73-80, doi:10.5194/isprsarchivesXL-5-W1-73-2013.

Frischer, B., 2003. Mission and recent Projects of the UCLA Cultural Virtual Reality Laboratory. *Virtual Retrospect 2003*, pp.65-74. <hal-01743231> (Accessed: 12 March 2024)

Frischer, B., 2003. Mission and recent Projects of the UCLA Cultural Virtual Reality Laboratory. *Virtual Retrospect 2003*, pp.65-74. <hal-01743231> (Accessed: 12 March 2024)

Gardin, P., Cesprini, M., *The Village Laboratory – Ghesc un borgo per imparare. Quaderni di Ghesc – Numero Zero*, 8-46

Grussenmeyer P., Landes T., Doneus M., Lermat J. L., 2018. Basics of range-based modelling techniques in Cultural Heritage. In Stylianidis E., Remondino, F. (Eds.), *3D recording, documentation and management of cultural heritage*, 305-368. Whittles Publishing. ISBN 978-1849951685

Guidi, G., Russo, M., & Beraldin, J., 2010. *Acquisizione 3D e modellazione poligonale*. Milano: McGraw-Hill.

Lou, M., 2019. Art historian's laser mapping project could help save Notre Dame. *CNN*. [online] Available at: <https://edition.cnn.com/style/article/notre-dame-andrew-tallon-laser-scan-trnd/index.html> (Accessed: 12 March 2024)

Marr, B, 2019. What Is Extended Reality Technology? A Simple Explanation For Anyone. *Forbes*. [online] Available at: <https://www.forbes.com/sites/bernardmarr/2019/08/12/what-is-extended-reality-technology-a-simple-explanation-for-anyone/?sh=3614d1ea7249> (Accessed on: 21 October 2023)

Remondino, F., 2011. Heritage recording and 3D modeling with photogrammetry and 3D scanning. *Remote Sensing*, 3.6, 1104-1138.

Sankar, A, 2019. *Design Architecture in Virtual Reality*. 1-1

Teruggi, S., Fassi, F., 2021. Mixed Reality for the Monumental Heritage. A First Test. In *Proceedings ARQUEOLÓGICA 2.0-9th International Congress & 3rd GEORES-GEOMatics and pREServation* (pp. 538-541). Universitat Politècnica de València.

Thrun S., 2007. Simultaneous Localization and Mapping. In: Jefferies, M.E., Yeap, WK. (eds) *Robotics and Cognitive Approaches to Spatial Mapping*. Springer Tracts in Advanced Robotics, vol 38. Springer, Berlin, Heidelberg. doi.org/10.1007/978-3-540-75388-9\_3

Vigliarolo, B., 2019. Augmented reality for business: Cheat sheet. *TechRepublic*. [online] Available at: <https://www.techrepublic.com/article/augmented-reality-for-business-cheat-sheet/> (Accessed on: 10 May 2023)

Vosselman, G., & Maas, H., 2012. *Airborne and terrestrial laser scanning*. CRC Press.

3D laboratory. (2023). Frank Lloyd Wright Foundation . Retrieved from <https://franklloydwright.org/3DLab/>

Agisoft Metashape . Software, Version 1.5.5. <https://www.agisoft.com> (Accessed: 19 March 2024)

Blender. Software, Version 4.0. <https://www.blender.org/> (Accessed: 19 March 2024)

Campi Scuola: Italia. Available at: <https://www.canovacanova.com/campi-scuola> (Accessed: 19 March 2024).

Duomo 4.0: New Experiences of Virtual Reality and Augmented Reality. (2023). Duomo di Milano. Available at: <https://www.duomomilano.it/en/duomo-4-0-virtual-reality-augmented-reality/> (Accessed: 18 March 2024)

VisitOssola, 2024: The History, Traditions and Folklore. 2019. Available at: <https://bit.ly/4cg4n3p> (Accessed: 12 March 2024)

Fiorillo, F., 2023. The photogrammetric survey: Image acquisition. Preservation and Digital Survey Class.

Fist Full of Shrimp, 2022. Unity VR Games Basics. YouTube. Available at: [https://www.youtube.com/playlist?list=PLX8u1QKI\\_yPDn0-\\_fMYjJ\\_5hIA397L-z6](https://www.youtube.com/playlist?list=PLX8u1QKI_yPDn0-_fMYjJ_5hIA397L-z6) (Accessed on: December 2024)

Frank Lloyd Wright Foundation, 2024: Welcome to the Frank Lloyd Wright Virtual Classroom. Available at: <https://franklloydwright.org/virtualclassroom/> (Accessed: 18 March 2024)

Frischer, B., 2023. Rome Reborn 4.0 Demo Reel. YouTube. <https://www.youtube.com/watch?v=s50hT6SOdl4> (Accessed: 12 March 2024)

Immersal, 2023. Immersal SDK. Available at: <https://immersal.gitbook.io/sdk> (Accessed on: August 2023)

Interaction Design Foundation - IxDF, 2016. What is User Interface (UI) Design?. Interaction Design Foundation - IxDF. <https://www.interaction-design.org/literature/topics/ui-design>

Laboratory of places 2017 ghesc and surround – 6th edition July 26 to August 4, 2017. Available at: <https://www.sitech-3dsurvey.polimi.it/?p=2204> (Accessed: 19 March 2024)

Laboratorio dei Luoghi I° edizione, 2012. Available at: <https://www.sitech-3dsurvey.polimi.it/?p=278> (Accessed: 19 March 2024)

Laboratorio dei luoghi 2016. Ghesc e dintorni. Storia, Rilievo, Evoluzione. Summer school: il rilievo per i Beni Culturali. Available at: <https://www.sitech-3dsurvey.polimi.it/?cat=3>. (Accessed: 19 March 2024)

Laboratory of Places 2011-2016. Available at: [https://www.sitech-3dsurvey.polimi.it/?page\\_id=328](https://www.sitech-3dsurvey.polimi.it/?page_id=328) (Accessed: 19 March 2024)

# sitography

Leica BLK Original, 2022. Digital Mapping for Augmented Reality AR with Leica BLK Autonomy and Immersal. YouTube. Available at: [https://www.youtube.com/watch?v=3XJdjag0q9A&t=4s&ab\\_channel=LeicaBLKOriginal](https://www.youtube.com/watch?v=3XJdjag0q9A&t=4s&ab_channel=LeicaBLKOriginal) (Accessed on: 23 September 2023)

Leica Geosystems, 2023: BLK2GO Handheld Imaging Laser Scanner. <https://shop.leica-geosystems.com/leica-blk/blk2go/overview> (Accessed: 12 June 2023)

Louvre, 2024: The mona lisa in virtual reality in your own home. Available at: <https://www.louvre.fr/en/what-s-on/life-at-the-museum/the-mona-lisa-in-virtual-reality-in-your-own-home> (Accessed: 18 March 2024)

Martínez, P., 2024. Different types of augmented reality. Onirix. [online] Available at: <https://www.onirix.com/learn-about-ar/types-of-augmented-reality/> (Accessed on: 7 February 2024)

Meta AR Developer Professional Certificate, 2024. Coursera. <https://www.coursera.org/professional-certificates/meta-ar-developer> (Accessed: 12 March 2024)

Meta Spark AR, 2024: Learn. <https://spark.meta.com/learn/> (Accessed: 12 March 2024)

Meta Spark Studio. Software, v179. <https://spark.meta.com/download/> (Accessed: 19 March 2024)

Picasso sculptor. matter and body. Guggenheim Museum Bilbao. <https://www.guggenheim-bilbao.eus/en/guggenheim-365/virtual-tour/picasso-sculptor-matter-and-body> (Accessed: 12 March 2024)

Unity, 2023: Unity User Manual 2022.3 (LTS). Available at: <https://docs.unity3d.com/Manual/UnityManual.html> (Accessed on: August 2023)

Unity. Software, Version 3.7.0. <https://unity.com/> (Accessed: 19 March 2024)

Valecillos, Dilmer, 2019. Augmented Reality Development Tutorials. Youtube. Available at: <https://www.youtube.com/playlist?list=PLQMQNmwnN3FvzFLpLRxA8Xa1zRypFeVav5> (Accessed: August 2023)

Valem, 2022. How to Make a VR Game in Unity 2022. Youtube. Available at: <https://www.youtube.com/playlist?list=PLpEoilH-4eP-OKItF8XNJ8y8e1asOJud> (Accessed on: 3 December 2024)

Vision Online Marketing Team, 2018. What is Visual SLAM Technology and What is it Used For? Association for Advancing Automation (A3). Available at: <https://www.automate.org/vision/blogs/what-is-visual-slam-technology-and-what-is-it-used-for> (Accessed on: 3 March 2024)

VectorNav, 2024: What is an Inertial Measurement Unit? Available at: <https://www.vectornav.com/resources/inertial-navigation-articles/what-is-an-inertial-measurement-unit-imu> (Accessed: 18 March 2024)

Velodyne Lidar, 2024: What is lidar? Available at: <https://velodynelidar.com/what-is-lidar/> (Accessed: 18 March 2024)

Weinstein, D., 2022. What Is Extended Reality? Nvidia. Available at: <https://blogs.nvidia.com/blog/what-is-extended-reality/> (Accessed on: 15 November 2023)

