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Heritage Duplication:

Analytical Study, Digitalization and Immersive Representation of Monza Park

Relatore: Prof. Cecilia Maria Bolognesi

Tesi di Laurea Magistrale di Yi Zhang, matricola 961716

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Digital Heritage VR Represent

tation Immersive

Abstract

Computer and scientific advancement has always encouraged us to explore the potential of the digital world. With the emergence of COVID-19 and the growing popularity of Metaverse and VR in the so-called web3.0 era, the realistic and immersive goal for the digital heritage has become more important. In recent years, an increasing number of scholars have begun to use and investigate the digitization approach to cultural resources. The vast literature consistently contributed conceptually and practically to new boundaries.

In this project, the researcher explores how the digital era affects the purpose of digital heritage and attempts to digitally duplicate Monza Park's historic buildings and landscape at a 1:1 scale. During study, the author determined that existing workflows cannot achieve the research purpose and advocated new ways based on a summary of technologies and tools in sample situations. The new workflow is designed in an innovative and efficient manner with a focus on the accurate depiction of material authenticity. The designed workflow is created from a scientific perspective, taking into account quality, simplicity, and efficiency in their entirety. In the paper, the author breaks down the practice stages in detail so that readers can follow along better. In addition, the data is captured at each step and assessed with graphical diagrams and charts to facilitate analysis. In conclusion, the overall strategy is evaluated critically and its limitations and additional potentials are discussed.

Astratto

Il progresso informatico e scientifico ci ha sempre incoraggiato a esplorare le potenzialità del mondo digitale. Con la nascita del COVID-19 e la crescente popolarità del Metaverso e della VR nella cosiddetta era del web3.0, l'obiettivo realistico e immersivo per il patrimonio digitale è diventato più importante. Negli ultimi anni, un numero crescente di studiosi ha iniziato a utilizzare e indagare l'approccio alla digitalizzazione delle risorse culturali. La vasta letteratura ha contribuito concettualmente e praticamente a esplorare nuovi confini.

In questo progetto, si esplora il modo in cui la tecnica digitale influisce sulla valorizzazione del patrimonio culturale e tenta di duplicare digitalmente gli edifici storici e il paesaggio del Parco di Monza con un dettaglio pari all' 1:50. la ricerca ha compreso come i flussi di lavoro esistenti non siano in grado di raggiungere gli obiettivi preposti in relazione alla verosimiglianza dei manufatti e ha proposto nuove modalità basate su una sintesi di tecnologie e strumenti in situazioni campione. Il nuovo flusso di lavoro è stato progettato in modo innovativo ed efficiente, con particolare attenzione alla accurata rappresentazione ed'autenticità dei materiali. Il flusso di lavoro progettato è stato creato da una prospettiva scientifica, tenendo conto di qualità, semplicità ed efficienza nella loro interezza. Nel documento, l'autore suddivide le fasi della pratica in dettaglio, in modo che i lettori possano seguire meglio il processo. I dati vengono acquisiti in ogni fase e valutati con diagrammi e grafici per facilitare l'analisi. In conclusione, la strategia complessiva viene valutata criticamente e ne vengono discussi i limiti e le potenzialità aggiuntive.

Introduction

The fast expansion of digital technologies had presented numerous sectors with both opportunities and challenges. In recent years, as a result of COVID-19, people have become more dependent than ever on the digital world and online services (Sun et al., 2020). From the evolution of the Internet, we can conclude that digitalization and online activities are becoming one of the most prevalent modes of daily life and investment. Its potential is frequently viewed as the future of human existence. (Kravchenko et al., 2019). With the advent of virtual reality(VR) and the emergence of the Metaverse and web3.0, people's expectations for information transmission in the digital world shifted from 2d to 3d, and the demand for a realistic and immersive experience became more pressing than ever. (Hoeber & Gorner, 2019) In 2020, the buzz surrounding the Metaverse will intensify, attracting academic and commercial interests. People feel that the capability of digital duplication to replace the physical world will become increasingly applicable. (Gaafar, 2021) With increasing numbers of VR applications and decreasing costs, immersive information sharing and a realistic virtual experience are now easily accessible. (Lee, Lee & Jeong, 2021)

In the meantime, the digital preservation of cultural assets and archaeological sites became increasingly prevalent due to the development of technology and techniques. To mention a few, the scan to BIM technique and photogrammetry technology for 3D survey, historic Building Information Modelling (HBIM) for representation, and eXtended Reality (XR) for distribution are a few examples (Jung et al., 2021; Pybus et al., 2019). As a result of the variety of computer-aided design (CAD) software, functions can be reached more easily than in the past.

How should we then seek potential in the sphere of digital heritage in this age? Virtual Reality (VR) is a key method for representation that extends our physical world experience to a simulated digital domain, transcending the limitations of time and distance, according to the literature review (Rushton, Silcock & Rogers, 2018). Communication and interaction play a crucial part in the interpretation of digital culture heritage in order to achieve successful information sharing and immersive embodied comprehension (Rahaman & Tan, 2011). And it is generally accepted that the standard work approach comprises three stages: documentation, representation, and dissemination (Alonzo, 2000). Recent research initiatives have demonstrated the viability of the most prevalent technologies in this field, such as the scan-to-BIM technique (Banfi, Brumana & Stanga, 2019; Bolognesi et al. 2021)

In this essay, the author summarizes existing concepts and methodologies and proposes a novel workflow with the goal of creating a genuine immersive experience. Alonzo C.'s conceptual framework is cited (Alonzo, 2000) and the practical method can be categorized as follows:

1.documentation: site survey with laser scanning and photogrammetry

2.representation: the combination of computerized and manual data manipulation. The creation of an immersive and realistic environment.

3.dissemination: integrate digital media into the project e.g. VR headset.

The structure of the paper is as follows: Capter 1 describes the purpose of the research by describing the relationship between web3.0 ideas and digital heritage through the use of case studies and research. Capter 2 showed the historical and geological significance of Monza Park's heritage value. Capter 3 designed the workflow with practical duplication techniques in mind. Capter 4 recorded the specific steps of the entire practice, validated the practicability of the designed process, and reported on future opportunities.

Research Goal

The objective of this project is to provide a scientific and efficient workflow for the realistic duplication of a heritage site, to generate a completely immersive virtual copy of any building with its environment. This research intends to create a fully immersive 1:1 scale virtual reality model of the heritage site at Monza Park, which is located to the north of Monza, Italy, so that it can be used in educational games or tourism in the future. Through VR technology, the initiative offers the chance to realistically explore an outdoor space.

Methodology

Theoretical Approach

● Case study: examining the interaction between Web 3.0, virtual reality (VR) concepts and digital heritage.

● Literature review: research digital heritage literature and projects in order to comprehend conceptual framework and applicability.

● Documentary research: Analyze recent research initiatives' methodologies and technologies.

Practical Approach

Utilizing the existing laser scan to BIM workflow and photogrammetry techniques, the practical methodology comprised the following steps:

● Compare the texture quality and work efficiency of various workflow software combinations.

● Exporting to Unreal Engine and creating 1:1 scale, completely immersive, interactive virtual reality models.

● Analysis and examination of data.

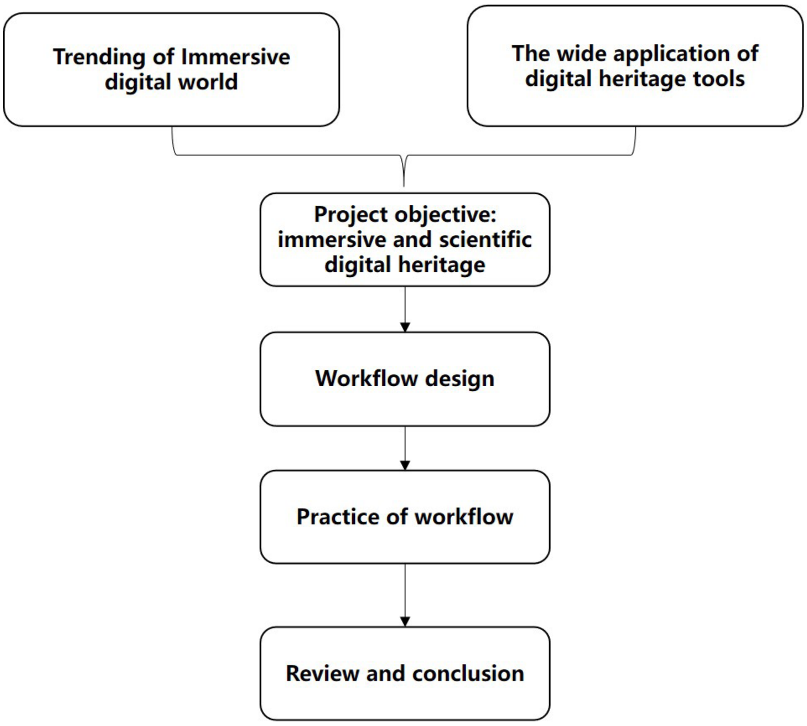


Fig1. Conceptual map (self drawing).

Content

Chapter1 **Background**

Web 3.0: The Digital Time

Web technology expands the digital universe in unprecedented ways. Spreading technologies such as decentralized and user-based features in Web 3.0 have prompted active discussion and encouragement in duplicating the real world into digital ones, while the desire for digital cultural heritage confronts its new chances and problems in this age.

Web3 is an Internet concept that combines block chain technology with a decentralized, currency-based economic system. Researchers and journalists have linked it to Web 2.0, stating that this data and content is comprised of small firms that are occasionally referred to as "big tech." In 2014, Gavin Wood, the founder of Ethereum, introduced the concept of "Web 3," which garnered significant interest from cryptocurrency enthusiasts, large tech businesses, and venture capitalists. According to some analysts, Web 3 will increase data security, scalability, and user privacy, as well as have an effect on large technological corporations. Others are concerned about a decentralized network in which privacy is threatened by the uncontrolled stream of damaging information that concentrates wealth on a small number of investors and individuals, or by huge data collecting. Centralization enables billions of individuals to participate in the Internet, thereby establishing a stable and robust infrastructure. Nonetheless, certain centralized institutions have their own strongholds in a variety of Internet disciplines and can decide for themselves what is and is not permitted. Web 3 is the answer to this issue. Web3 is a user-created, user-operated, and user-

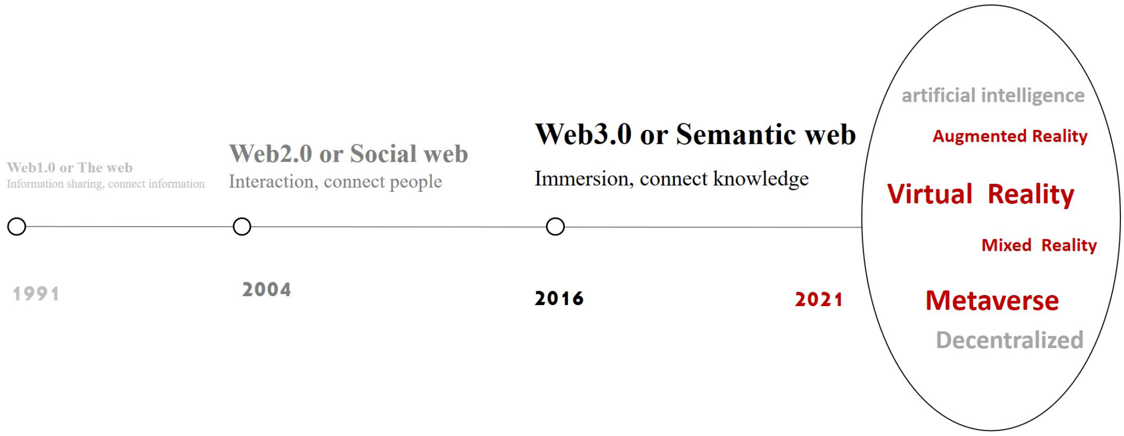


Fig2. The timeline from web1.0 to web3.0 (self drawing).

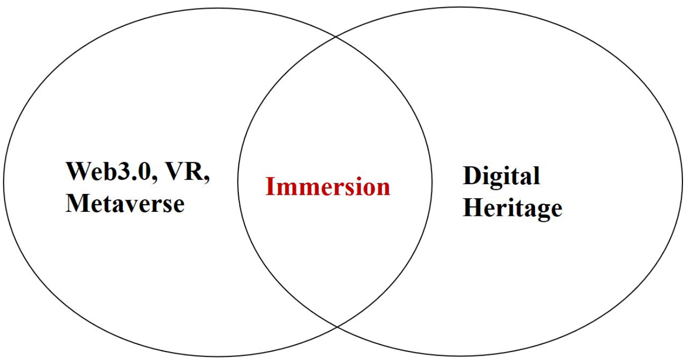


Fig3. The timeline from web1.0 to web3.0 (self drawing).

owned decentralized web. Web3 places authority in the hands of individuals as opposed to corporations. Before discussing Web3, we must first understand how it is accomplished. Defining Web3 precisely is difficult, although the concept is guided by a number of guiding principles.

1. Web 3 is a decentralized network: it will not be owned or controlled by a centralized entity, but rather distributed among its designers and users.
2. Web 3 has no access restrictions; everyone has equal participation rights, and nobody is excluded.
3. Web 3 has its own payment strategy, as it performs online spending and transfers using cryptocurrency instead of depending on antiquated banks and payment processors.
4. Web 3 functions on the basis of incentives and economic mechanisms as opposed to relying on trusted third parties.

To comprehend the evolution of web3.0, we can examine the chronology of internet development for hints on how the internet became as powerful as it is now. In the web 1.0 era (1991–2004), the technologies and productivity of computer science restricted the use of digital tools in a more professional setting. Cost of computer production, hardware performance, and user count are the determining factors in these constraints. Under these conditions, the Internet was mostly utilized by professional researchers or for publishing information unilaterally to a small number of users. Then, a decade later, at the turn of the 21st century, the Internet entered the web 2.0 era with the proliferation of personal computers and advancements in computer science. It made the digital experience it delivered to people's daily lives more public and widespread. Users become increasingly active and integrated with a variety of applications. Internet's growing popularity is due to the increasing ability to post information and communicate with others. People were growing increasingly dependent on digital instruments due to their pervasiveness in all facets of daily life. Since 2016, Web 3 is socially accepted as the current stage of internet development.

It is evidence that, from a developmental standpoint, Web 3 will usher in a new era in daily life, particularly for its use in digital approaches and technologies. With its broader applicability, its characteristics can lead to advancements in other areas, including heritage preservation, as we explore in this essay. With increased demand, digital assets increasingly predominate in the Web 3 age. Its "real-world parallel" mission encourages research towards virtual reality experiences that are more realistic and immersive.

Rising of Virtual Reality and Metaverse

Virtual Reality and Metaverse are two of the most important concepts of the Web 3 era, which also has a strong connection to digital heritage in terms of the digital duplication. The use of VR contributes to the depiction and diffusion of digital objects, delivering virtual content to the public in a manner that is most immersive and comprehensive. In the meantime, Metaverse is a robust notion for a future digital society biult on the VR technology, in which everything in the physical world will have a digital counterpart that people can hold and live with. In recent years, the concept of virtual reality (VR) and the Metaverse has grown in popularity and recognition. Understanding these notions will allow us to construct a clearer framework of the opportunities and obstacles that the digital heritage is facing.

Virtual Reality(VR) is a practical technology trying to combine the physical world with digital ones by creating virtual graphics independently for the different recognizing system of two eyes. Its development is closely related to computer science, digital information technology and simulation technology. Theoretically, VR technology is a computer simulation framework that allows people to create and experience immersive virtual world. It can document the information from physical word and transfer through digital media and represented in an immersive way contributed by VR equipment. Not only it can bring the exist physical world information, but also people can create own 3D objects that do not exist by the assistant of 3D recreation software. Nowadays, with the improvement of technologies, it is getting harder to tell the difference from real word and virtual ones. The VR equipment today can enhance user's immersive experience by auditory, visual, tactile, and other perception systems. The virtual reality is named this way for its ability to allow people immersed in the digital environment which is just like real word experience.

The development of VR has a long history. To start with, the concept of VR was first emerged firstly in 1838. British physicist Charles Wheatstone introduced the concept of stereo vision to the world. The technology increased the sense of reality firstly by overlapping visual fields produced by each eye. In this way the brain center synthesized the visual signals from the two eyes into a complete, deep and three-dimensional image. The principle then began to become the foundation of virtual reality technology, upon which, Brewster Davey invented first portable 3D VR glasses in 1849 named Lenticular Stereoscope. The virtual reality world became close to the life in the first time. Then, in 1929, the technology was first applied commercially in the industry for pilot training. The world's first flight simulator was invented by Coach Link thanks to the use of pumps, valves, etc. The simulator allows pilots to experience exactly what it is like to control an aircraft. This technology once trained over 500,000 pilots from all over the world. In the mid 1950s cinematographer Morton Heilig developed the Sensorama (patented 1962) which was an arcade-style theatre cabinet that would stimulate all the senses, not just sight and sound. It featured stereo speakers, a stereoscopic 3D display, fans, smell generators and a vibrating chair. The Sensorama was intended to fully immerse the individual in the film. The public and commercial industry began to pay more attention for its potentiality for immersive experience. In 1968, the virtual reality was first connected to the computer instead of camera. The head-mounted display (HMD) product was named

"The Sword of Damocles" for its heavy structure suspended from the ceiling above the user. However, with the effort of scientists and engineers, the HMD become lighter for commercial usage after 16 years. In 1984, Jaren Lanier and Thomas Zimmerman formally named the field “Virtual Reality” by their success in establishing the first company to sell VR glasses and gloves. Later, with the improvement of 30 years, the VR was able to provide a 90 degree vision field and be developed as the Oculus prototype. In 2014, the Oculuse VR was acquitted by face book with $2 billion and start to be valued and widely applied in many other companies. As a result, the first version of VR Oculus Rift equipment was published in 2016 and keep updated in the following years. Then, most recently, in 2021, as is known by the public for its shocking movement, the Facebook CEO Mark Elliot Zuckerberg changed its company name to Meta as a referring to Metaworld to develop the further potential in virtual reality.

Metaverse is a concept aimed to combine virtual reality technology with block chain to allow the possibility of a new mode in exchange goods with digital currency. (Sparkes, 2021). Theoretically, it is a hypothetical iteration of the Internet as a single, universal and immersive virtual world that is facilitated by the use of virtual reality (VR) and augmented reality (AR) headsets. In practice, metaverse more related to the social connection through virtual 3D world. (https://en.wikipedia.org/wiki/Metaverse) In the common language, imagine the Metaverse more like a digital tool to allow people live a parallel life in visual world. In this digital world, everything appears just like the real ones. People can travel between different spaces with immersive experience through VR equipment. And the goods can be traded freely in a value system parallel to real world currency, with the protection of absolute safety by block chain technology. Imagine

Fig4. Rising of VR and Metaverse (self drawing).

you can dancing in the night club with friends with immersive face to face experience and racing the cars to win the money that can be exchanged to dollars and buy real goods in physical world. The spread concept of Metaverse encouraged people to extend the boundary of their lifestyle.

The concept was firstly promoted by Neil Stephenson in late 20th from his science fiction novel “Snow Crush” , in which he described a scene where humans, as programmable avatars, interact with each other and software agents, in a 3D virtual space parallel to real world. Then, in 2011 another science fiction Ready Player One by Ernest Cline created a story of a visual landscape called "The OASIS". In the oasis, all the social activity can happen, but by the visual actors controlled by real players behind the VR headset. The novel imagined a brand new social structure where the visual game become so popular that everyone on earth is involved. The novel also described that the value and order is re-framed in this Metaverse social system, where people no longer enjoy from real world with fresh airs and natural loves, but addicted in the power and wealth in visual world. The novel was adapted to film in 2018 $500 million box office. In 2021, Mark Zuckerberg changed the name of his social media company from “Facebook”to “Meta”, which announced the dedication to "Metaverse". This is going to be a very big part of the next chapter for the tech industry, network president Mark Zuckerberg told The Verge, noting that "Metaverse is the heir to the mobile Internet ". (Al Ain News 2021) He wants to know the “Facebook” as the Metaverse Company, not Social Media Company. (Conversation Newsletter 2021)

Statistical data also proved the popularity of Metaverse. In the late 2021, as global internet users found that the obstacles in real world that prevent them from doing something can be easily perceived from the implement of Metaverse, a survey was carried out to study people's attitude towards this rising concept. The survey indicated the public expectations on the field that Metaverse. The most evidenced point is that over one third of users believed that the Metaverse can improve the life quality by many aspects e.g. enhance creativity and imagination, traveling the world without moving, increasing technological literacy and skills. It's application is promising in both education and career perspectives.https://www.statista.com/statistics/1285117/metaverse-benefits/

The Metaverse concept broaden our imagination for future digital worlds. However, to be practical, how can we benefit from these techniques? To figure out the importance of the concept, we can find some clues from their recent applications in our daily life.

Application in Industries

Today, virtual reality technology and the Metaverse are increasingly integrated into daily life. One of the strongest indicators is the revenue of virtual reality games. In 2017, VR gaming generated a revenue of only $0.4 billion, but by 2021, that number will have increased by around 20% annually to reach $1.4 billion. (https://www.statista.com/statistics/499714/global-virtual-reality-gaming-sales-revenue/) Likewise, the VR hardware market is optimistic. It is anticipated that by 2028, the market for XR hardware will reach 252.16 million US dollars, up from 27.96 billion dollars in 2021. (https://www.statista.com/statistics/591181/global-augmented-virtual-reality-market-size/) Moreover, with the application of VR and the notion of the Metaverse, we are able to see an increasing number of events in daily life. In the following paragraphs, we will learn about a few industries.

In the tourism business, virtual reality technology allows travelers to experience ancient buildings' historical characteristics in an immersive manner. This feature facilitated several online tours of cultural heritages, particularly during the lockdown period. The number of online visitors increased by forty percent due to the virtual museum and interactive web media. 2020: The Network of European Museum Organisations. NEMO report on the effects of COVID-19 on European museums. https://www.ne-mo.org/fileadmin/Dateien/ public/NEMO documents/NEMO COVID19 Report 12.05.2020.pdf These instruments presented both tourists and management with new opportunities and difficulties. At the

Colosseum in Rome, digital experts created a comprehensive, interactive 3D reproduction of the structures in their original scale and with a wealth of details. The self-guided system was built as an internet application with VR headset connectivity capability. Thus, the application enables visitors to immerse themselves in the virtual reality setting. Researchers in the heritage and archeology fields concur that this type of creative

Fig5. Travis Scott's metaverse concert attracted 2millions of online participants. (https://deciliiter.net/the-metaverse-our-destination-in-2049)

Fig6. Travis Scott's metaverse concert attracted 2millions of online participants. (https://coinyuppie.com/justin-biebers-first-metaverse-concert-surprised-the-world/)

tourism is crucial to the protection of cultural resources. (Tan, 2015). Not only can it replicate the tourism experience digitally, but it also enables individuals to travel anywhere without leaving their homes. We can conclude that the implementation of digital heritage technologies in tourism can increase the information's global dissemination and digitally archive it for future research and assessments.

In addition, virtual reality technology expanded in the arts and entertainment industries. In 2021, "Fortnite" staged a virtual concert by the musician Travis Scott. The event had a significant societal impact as it attracted a total of 12 million spectators from around the world, with more than 2 million watching simultaneously online. The event utilized the Metaverse concept with the help of NFT (non-fungible token) technology. Each player and object in this framework has a unique identity related to the actual world. Visual recreations of the concert's atmosphere created a frightening experience. During the concert, players can freely walk inside a 3D environment with varying backgrounds. In the beginning, for instance, the audience was on the ground watching the performer, who was artistically rendered as a gigantic. Then, as the song reached its crescendo, the crowd was instantly lifted into the air and propelled into the universe together with the singer. In addition, this voyage included other stunning scenes such as the deep ocean and the wild forest for a colorfully distinct experience. During the event, players can also engage with others through gestures and messaging. Concert attendees were so energized by the concert's ambiance and music, which were harmoniously paired. The critics subsequently described it as "beautiful" and "outstanding." People are shocked by the success of the virtual concert and are more excited about the future of virtual reality technology with the Metaverse concept.

(Rijmenam, 2022).

The virtual reality (VR) technology's contribution to education is especially remarkable since it connects teachers and students in multiple dimensions (Freina & Ott, 2015). Using architectural education as an example, the application of various VR and AR technologies may exhibit 3D models in a more comprehensive

Fig7. Education: VR usage in architecture education at NSC for better understanding of space (https://archinect.com/news/article/150120672/how-vr-may-be-the-bridge-firms-and-educators-need-to-share-architecture).

Fig8. AR equipment in Architecture, engineering and construction(AEC) industry(https://redshift.autodesk.fr/what-is-augmented-reality/).

manner, vastly enhancing the quality of communication when discussing architecture form and space. Multiple VR headsets, such as the Oculus Rift, HTC Vive, Samsung Gear VR, and the low-tech Google Card Board, are affordable for colleges to introduce into the classroom. Through the immersive experience, educators and students are also able to communicate more effectively regarding spatial cognition. (Wang et al., 2018).

In recent years, virtual reality technology has also provided administrative help to the architectural engineering and construction (AEC) sector. (Wen & Gheisari 2020). In implementing previews, existing technologies can merge VR and AR technology with BIM models and functionality. To integrate VR devices with existing templates, it is typically necessary to perform secondary development in tools such as Revit or import 3D models into game engines such as Unity or Unreal (Hollerer, 2004). Its advantage is that it can deliver real-time immersive previews at each stage of the building's development, from the spatial prototype during conceptual design to the size during architectural design to the material selection during interior design (Alizadehsalehi, Hadavi & Huang 2020).

As is evident from the preceding, in the era of Web 3.0, immersive virtual experiences are becoming increasingly popular and highlighted. How therefore might we record and preserve historical memory more effectively? Using digital technology to document historical buildings can preserve the database's legacy worth through generations, time, distance, and location (Huggett, 2020). However, how can we preserve the historical flavor within the digital model, and how can the digital model interpret the memory in the context of the web3.0 era so that it is immersive and representative for users? What should a digital heritage look like in the web 3.0 era, and how can we attain it?

Digital Heritage: Literature Review

Numerous researchers of the present day have analyzed the notion and structure of digital heritage. By studying the relevant literature, we can investigate and evaluate the primary problems and inherent nature of digital heritage.

Generally speaking, the work strategy for digital heritage projects can be categorized into three steps: documentation, representation, and dissemination. The documentation focuses primarily on the physical study of structures by methods of field surveying, construction literature review, infrared scanning, photogrammetry, and other techniques. The information is logged. Representation relates mostly to the visual replication of recorded data, such as modeling surveying and mapping data into a computer-generated 3D model. On the obtained digital model, 3D distribution provides an enhanced VR or AR expression to deliver a more immersive sensory experience for the outside world. The author concludes the study with a highly optimistic outlook for the application of virtual reality in the realm of digital heritage. Alonzo C. Addiso proposed the three strategy in 2000 at the opportune time. He believes that virtual reality can help individuals communicate more effectively and scientifically by incorporating nature, architecture, and people. Educational institutions, scientific institutions, and cultural institutions can all profit from this (Addison, 2000)..

Intangible digital heritage provides significant significance to cultural heritage conservation. According to Hannah Rushton, its significance can be summed up in three aspects. First, digital legacy prolongs the lifespan of cultural structures. The building's 3D information can be permanently kept in the computer as data for use by future generations. Second, digital heritage permits the presentation of buildings on computer displays, so transcending the limitations of space. Through computer platforms, researchers can undertake thorough observation and research on structures at any time and in any location. This immateriality greatly facilitates the study of cultural heritage. Finally, virtual reality technology allows the observer to interact with digital heritage. Virtual reality (VR) and augmented reality (AR) technologies allow people to explore cultural heritage architectural sites anywhere and feel the sensory shock they bring. This type of shock frequently remains in the user's heart for a long time, allowing the user to uncover more meanings through experiencing the historical structure (Rushton, Silcock& Rogers, 2018).

Given that the digital heritage project can have such a significant influence, how can it improve its information sharing? What aspects of the design process should be prioritized in order to impress and move users? After examining the technique of the digital heritage process and the application of the project's results, a better grasp of its interpretation and interaction design is required. We feel that there are four primary strategies to enhance the quality of digital heritage projects. (Rahaman & Tan, 2011) A strong digital heritage project must begin with an effective presentation. Diverse content, differentiation between distinct ideas, and narrative in the presentation process are all elements that might affect the presentation's quality. In the presenting process, we should prioritize short and clear expression and consider the user's perspective. Second, since the goal of digital architecture is to showcase its cultural worth more effectively, we

3 domains of digital heritage approach

- 3D documentation (from site surveys to digital resource)
- 3D representation (from historic reconstruction to visualization)
- 3D dissemination (from visualization to immersive networked worlds and augmented reality).

Emerging Trends in Virtual Heritage.
Alonzo C. Addison. 2000. IEEE MultiMedia 7 (2)

3 perspective of intangible value

- Extend life circle
- Provides dynamic observation and study.
- derive meaning by virtual experience.

The Tangible And Intangible: Interpreting Modern Architectural Heritage In Virtual Realities
Rushton H, Silcock D. 2018. Design, Social And Cultural Critiques On The Past, Present And The Future, 2018.

4 aspects of interpretation

- presentation
- cultural learning
- embodiment
- dialogic interaction

Interpreting Digital Heritage: A Conceptual Model with End-Users' Perspective.
Rahaman H, Tan B-K.. 2011. International Journal of Architectural Computing.

Fig9. Literature review of concepts in digital heritage (self drawing).

should prioritize cultural learning in design. In the process, we must condense the primary narrative of the cultural heritage so that it is simply comprehended by users. In order to further pique the interest of users in cultural learning, we can also allow them to participate with the learning content through Q&A, comments, and competitions. Additionally, embodiment can enhance the user experience of digital heritage projects. The emphasis of embodiment is on active engagement, task completion, and real-time feedback. These enhancements can also result in higher-quality digital heritage projects. Lastly, we can attain a more accurate understanding through enhancing dialogic engagement. For instance, enhancing the interaction between participants and specialists can improve comprehension of the material (Rushton, Silcock& Rogers, 2018).

The application of digital heritage technologies plays a significant role in the preservation of historic structures and diffusion of culture (MacDonald, 2006). Through the use of digital heritage technology, cultural heritage has been meticulously documented and conserved over the ages. To preserve history and culture in the present day, it is also spread via the Internet. In the process of communication, recorded historical buildings are exhibited to the public in a range of interactive formats, and the public can simultaneously raise awareness of the importance of preserving ancient heritage (Din & Wu, 2014).

Theoretically, based on a review of the relevant literature, the author concludes that digital heritage can be defined as a bridge between the past and the future, interpreting virtual 3D models from documented data to users in order to highlight the importance of heritage and culture more effectively. However, where are these results implemented practically? How were these aims accomplished? What are the particular tools and means? To answer these problems, we must examine some classic cases thoroughly in order to assess the viability of digitizing heritage in the present day.

Case Studies

To comprehend the impact that digital heritage can have, case studies are mandatory. By examining the digital tools and techniques utilized in these practices, we can gain an understanding of their potential for preservation, dissemination and so on. In this section, we examined three cases, two of which are related to the 2019 Notre Dame Cathedral fire in Paris. The contribution of digital techniques to the repair and restoration of burned ash is substantial. Case 1 focuses on the digital methods used to document the physical condition, whereas Case 2 focuses on how an immersive, accurate replica of a church was created in a video game and what it inspires. The final case examines a digital heritage preservation organization and some of its projects. The objective is to determine how effectively a well-designed user interface with abundant content can attract public attention to digital heritage.

Case1: Digital documentation of the burned Notre Dame Cathedral

Digital approaches are excellent for the documenting and preservation of cultural assets. The Notre Dame cathedral was destroyed by fire in 2019, and digital techniques aided irreplaceably in its reconstruction and documentation. Its "from laser scan to BIM platform" methodology enables future research, analysis, and maintenance (Al-Muqdadi, 2020). Thus, the heritage can survive permanently, be accessible via digital media, and be available to people all over the world.

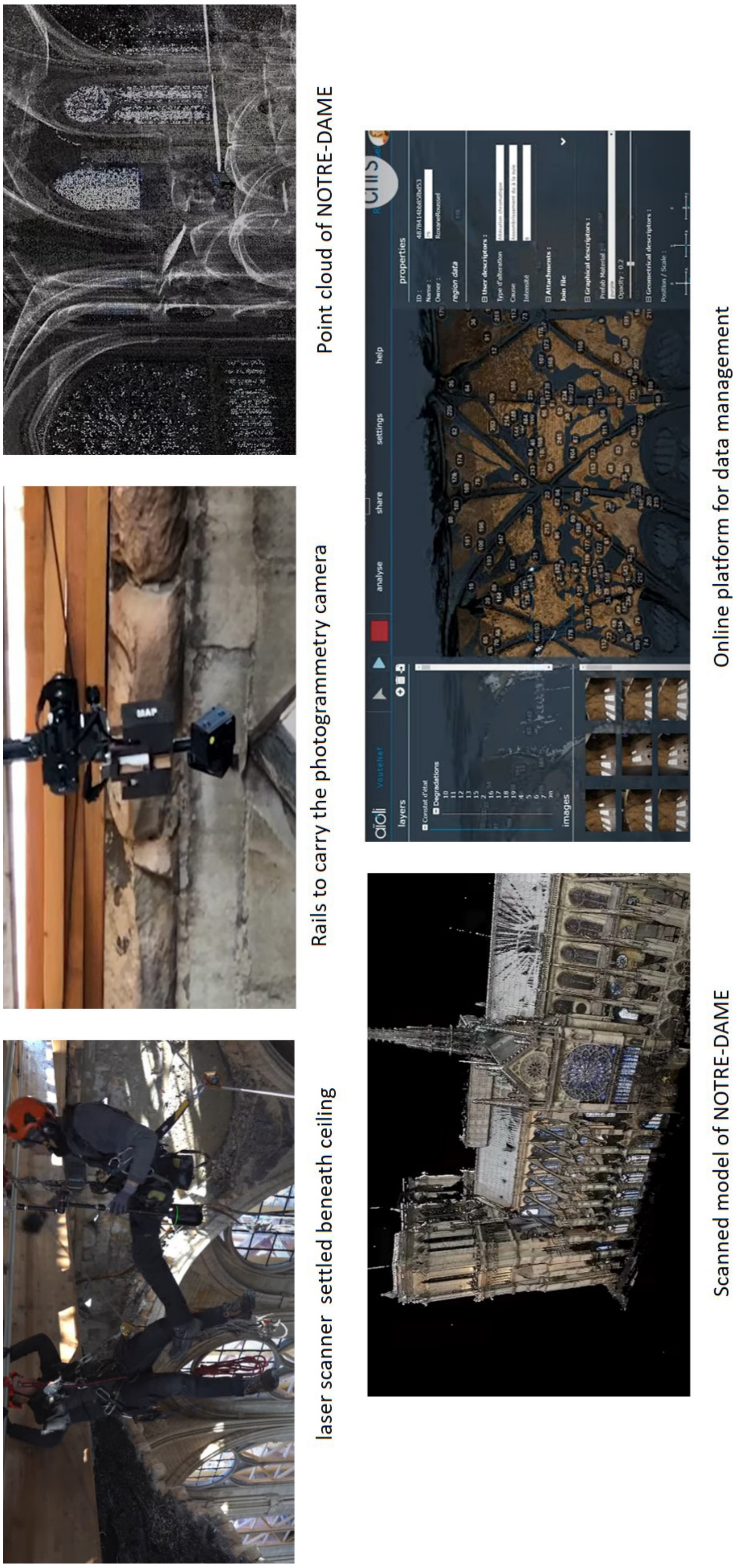


Fig10. Precise digital documentation: NOTRE DAME after burned(screenshots from https://www.youtube.com/watch?v=p-2J0H5i6-4)

Notre Dame Cathedral is one of France's most recognizable landmarks. The Notre-Dame de Paris was severely damaged by fire on April 15, 2019. The church's roof was severely damaged by fire, and its spire had collapsed. The French president, Emmanuel Macron, started a fundraising effort that garnered almost €1 billion in commitments. The fire chaplain is lauded as a hero in the Notre Dame fire. 17 April 2019 AP News, retrieved 12 April 2020). After the fire, more than fifty study teams were investigating the church's damage and repair options. Using infrared scanning technology, a digital team known as CNRS has created an exact scanning model and digital twin of Notre Dame Cathedral following the fire. The team had to put the scanning gear in the exact middle of the ceiling in order to cover all areas. By calculating the reflection of the beams, the scanning device may record the building's 3D information and generate thousands of recorded points every second with an error of only a few millimeters. After repeatedly scanning the object, the team loaded the acquired point cloud data into the digital platform system. The team's platform system is accessible to all scholars and conservators, and all recorded information is available to the public. On this platform, users can supplement the information captured by the platform, thereby enabling the platform to achieve sustainable development. (Notre-Dame: Construction of a Digital Twin | CNRS in English. https://www.youtube.com/watch?v=p-2J0H5i6-4.)

This case illustrates the significance of digital technology for the preservation, documentation, and repair of historic structures. Through the use of digital technology, the history of an 800-year-old building is recorded and preserved, allowing it to rise from the ashes.

Fig11. Gaming screenshot of NOTRE-DAME from assassin's creed(https://www.
jzhonker.com/2693.html)

Case 2: The Representation of Heritage in the Computer Game Assassin's Creed

Additionally, the casino sector has contributed significantly to the preservation of historic sites. In games with a historical setting, ancient atmosphere with old towns and cultural heritages are always portrayed to provide players an immersive feeling (Chapman, 2016). In many games, the requirements for the authenticity of historical structures may be exceedingly stringent. Assassin's Creed is a 3A RPG computer game with a medieval European historical setting. This game's depiction of historical structures is regarded as exemplary within the gaming industry. The production crew was able to recreate numerous European cities and monuments in the game's background with beautiful precision. How Ubisoft reconstructed Notre Dame for Assassin's Creed Unity. https://blog.siggraph.org/2019/05/how-ubisoft-re-created-notre-dame-for-assassins-creed-unity.html/. 2019)

Notre Dame de Paris is the most well-known reproduction of a building. The majority of the game's models are created using modeling software such as 3Dmas, Maya, and material manufacturing software like substance painter. For a model as iconic and precise as Notre Dame de Paris, the crew can only spend additional time painstakingly refining the details. The digital experts worked a half-year using visual references, home designs, and field measurements to create the computer model of Notre Dame de Paris. Due to the great precision and authenticity of the finished model, it was once suggested that the burned portion of Notre Dame de Paris be rebuilt using the game's model as a guide (Cozzen & Tracy, 2019). This suggestion is not rigorous enough to be implemented, but it does demonstrate the influence of game scene design on the cultural heritage industry.

The purpose of the structures in this game is to offer gamers with an immersive experience. Despite the fact that exact construction information is not retrieved through laser scanning, this event has enormous cultural relevance. Due of the immersive entertainment experience, users frequently express awe at the game's gorgeous historical structures. This will definitely pique their interest in cultural heritage, and they will anticipate learning more about it in the real world (Mochocki, 2021).

Case3.Cyark Projects and Dissemination

CyArk is one of the largest organizations dedicated to the preservation of cultural assets. Their primary objective is to strengthen ties to historic sites. Through place-based web, mobile, and other immersive channels, audiences were successfully connected to heritage. They documented historic structures of varying size and condition from many continents. To document historical memory, a combination of technologies including laser scan, photogrammetry, and drone aerial imaging was utilized. The relevance and caliber of their work can be determined by

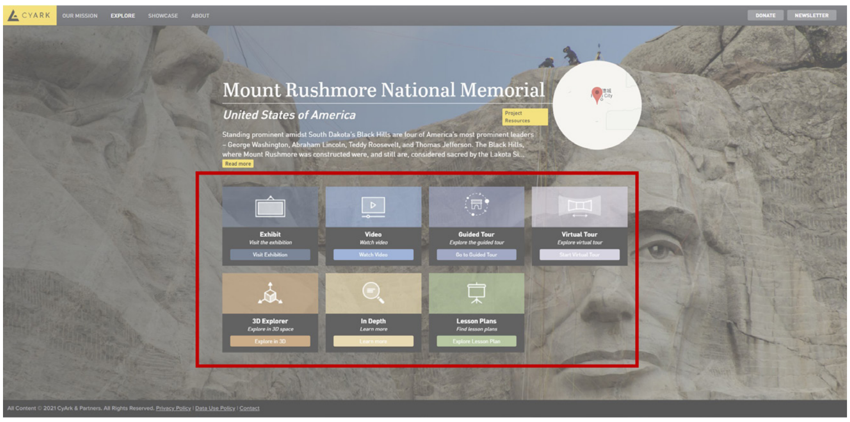


Fig12. The interface design of Mount Rushmore National Memorial Digital Model by Cyark(self drawing).

(a) Scanned model with natural environment and guided tour
(b) 360° presentation of single detailed building
(c) model with artificiall texture
(d) Immersive scanned environment with guided tour and layered UI design

Fig13. Digital reconstruction projects by Cyark(self drawing).

perusing the majority of their initiatives that were made available to the public online and for free. Not only does Cyark's heritage protection meticulously document the cultural heritage, but it also makes the cultural heritage model more appealing to the public through good interaction design and online development (Underhill, 2018).

In its project titled "Digital Documentation & Training at the Busanyin Shrine, Osun Osogbo," the Busanyin Shrine in Osun Osogbo was used. The scanned model comprises both the structure of the building and the surrounding area. The user interface design includes an option for self-guided exploration. Users can access the project's website, which features a 3D environment and voice instructions. To navigate the virtual space, they can use the arrow keys on the keyboard.

Mount Rushmore National Memorial, another of its projects, employs a combination of representation techniques to allow visitors to grasp the heritage in greater depth. The website incorporates numerous functions on a single display. In a planned show, visitors can learn the historical context using a clickable interface. They can gain access to a 3D physical experience by navigating a panoramic photo virtual tour and viewing a digital model made using aerial drone photogrammetry. If guests are interested in learning more, they can access films and documentation pertaining to the project via easy links.

CyArk's projects are represented in a wide variety of ways. Web-heritage connectivity is demonstrated by a 3D guided trip, a VR depiction, and an online 3D model viewer. Each project has its own unique representation feature for a specific purpose. We can learn from the interaction between digital heritage representation and distribution by providing a few examples.

Research Project Studies

As we are already familiar with the techniques and methods of digital heritage as a tool for preserving culture and giving value to the public, this section will be brief. Then, how are these digital models documented, and what methods are used? Through the examination of the most recent research project, we may become familiar with the distinctive workflow and technical approach of digital heritage.

1.Virtual Historical Reconstruction of Milan's Cerchia Dei Navigli:
In the year 2020, a study team attempted to recreate the ancient canals and water basins of Milan's Conca dell'Incoronata. Photogrammetry and Unreal Engine4 (UE4) interactive technologies were utilized to generate three-dimensional models for this project. It emphasized the viability of emotionally engaging historical sites through interactive design and material authenticity in order to resurrect the memories of their significant historical context (Banfi, Bolognesi, Bonini, & Mandelli, 2021).

The team uses laser scan and photogrammetry tools for the 3D surveying procedure, as well as historical records and construction blueprints for extensive research. Leica BLK 360 (a lightweight and portable laser scanner with a resolution of 5 mm @ 10 m of distance and a precision of 4 mm @ 10 m) and Leica TS12 software developed the accurate geometry. The scans were exported in the.e57 format for use as a NURBS modeling aid in Mc Neel Rhinoceros 7. On the other hand, the photogrammetry

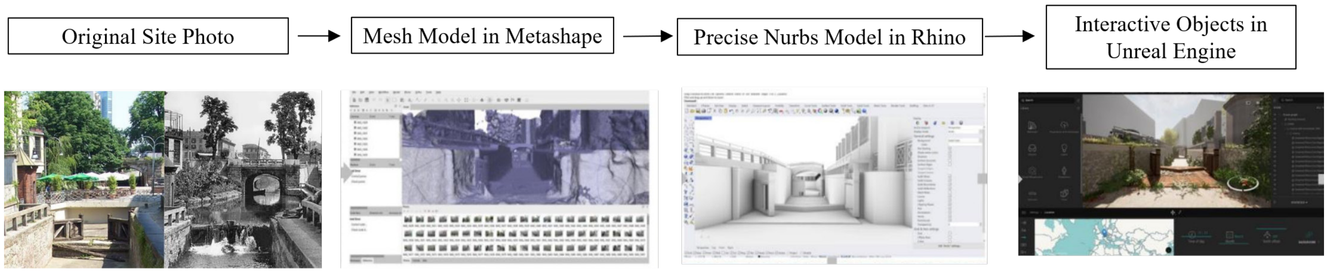


Fig14. Digital workflow of THE CERCHIA DEI NAVIGLI reconstruction (case2, self drawing).

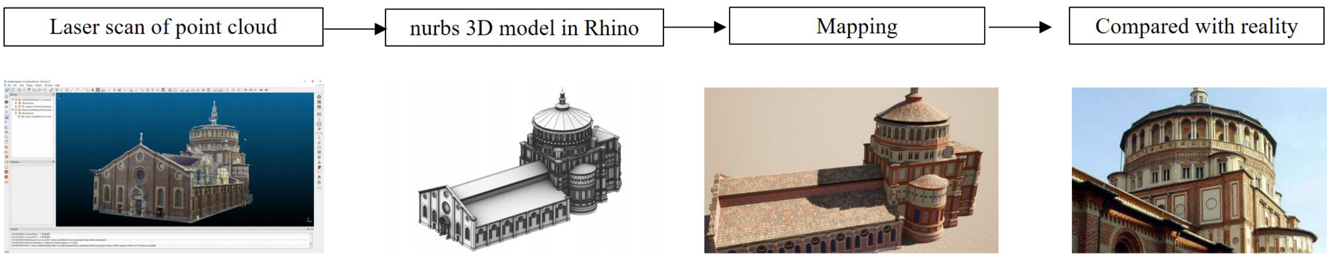


Fig15. Digital workflow of Santa Maria Delle Grazie reconstruction (case3, self drawing).

process in software Agisoft Metashape was applied to images captured with a Nikon D90 camera equipped with an 18 mm lens; here, it was possible to generate a high-resolution 3D model using the same reference system as the laser acquisition and orthophotos exported in.jpg format to map the 3D NURBS model in Rhinoceros 7. The mapped model can then be imported into Unreal Engine as a static mesh to implement interactive functionality and connect VR headsets.

Compared to the Sant 'Ambrogio research project, the building style is better represented by the texture form orthophoto than by the material library. However, no consideration is given to the coherence of vegetation. The virtual recreation eliminates the original wall's vines and brush. From a historical standpoint, it is possible that this might provide a false sense of the environment.

2.The Digital Reconstruction Of Santa Maria Delle Grazie's Convent In Milan

Santa Maria Delle Grazie was successfully digitized using a scan-to-BIM technique with an added focus on achieving realistic texturing (Bolognesi & Aiello, 2020). The texture was extracted from a photograph of the place and processed in Photoshop to create a seamless texture or a borderless image. The conversion from 2D to 3D is performed with Rhinoceros7. The textured model can be exported in fbx or obj format and will play flawlessly with various 3D recreation and representation programs.This project's texturing effort can be summarized in three areas.

1.Adjust surface directions: The material required to comprehend the face direction, which is not visible in Rhinoceros, must be employed. However, when imported into other visualization programs, such as Unreal Engine 4 and Unity, the incorrect direction would create issues. Some of the faces will be obscured. It will be necessary to utilize the "Invert Direction" or "Dir" command printed in the Rhinoceros7 software command bar until the entire model has the correct orientation.

2.Create seamless texture maps The project extracted only a section of the texture from the site photographs as material. Then, using computer graphics tools, a continuous texture or image without borders can be created. The benefit of the texture is that, when applied to a model's surface, it does not produce two identical but distinct images, but rather a single texture.

Mapping is the procedure of applying a 2D image to a 3D model. Each model surface has its own "texture direction." The surface of the scanned 3D model was maintained as a default square with the same dimensions. Consider that the direction and scale of bricks and roof tiles are defined parameters rather than the system's default value. On a three-dimensional model used to map a two-dimensional image, these directions are therefore always utilized as a mapping channel containing mapping parameters. Textures are applied to objects via the relevant channel. By applying the predefined UV channels to objects, it is possible to obtain a model with the correct texture scale and orientation.

This project places a great deal of emphasis on the texture in order to generate a historical flavor. The texture is neatly mapped and well represented. However, the repetitive texture tiling still loses a great deal of information compared to the real-world heritage. The workflow texture cannot accommodate the varying decays of the complex surface.

Review of Technologies and Tools

From the analysis of these studies, we may deduce several typical technological applications and the related gears. During the 3D survey era, the laser scan and photogrammetry are the most important methods. The data must be entered into the computer for processing and transfer into the building information model (BIM), which is represented by numerous software platforms. Through these platforms, the VR headset may be readily connected to the BIM model.

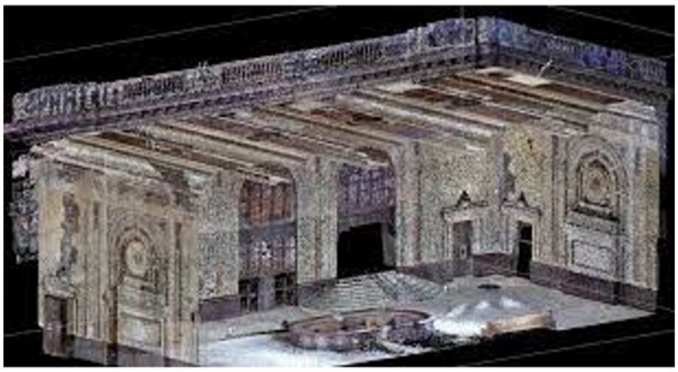
By calculating the reflection of rays, a laser scanner can record 3D information about objects. These data are always stored as point clouds. Due to the limited detecting range of the scanner, numerous scans are always required to document a single structure. In addition, the portability and size of the scanner must be taken into account if it must be transported to the site and installed in specified positions around the research subject. Common digital heritage documentation products include FOCUS 3D and RTC360 3D. Both are lightweight and capable of 5 mm @ 10 m distance resolution and 4 mm @ 10 m distance precision.

Photogrammetry is another prevalent digital recording technique for historic structures. The principle of photogrammetry is to take a vast quantity of photographs that encompass the entire thing. (Cabrelles et al., 2009). To enable the reorganization of computer software, the photograph must be able to overlap with more than 50 percent of its neighboring images. Photogrammetry is simpler than laser scanning in that the researcher merely needs to carry a camera to "overwhelmingly" photograph the target objects. After transferring the images to professional photogrammetry software, point clouds and mesh models can be generated. Finally, the mesh model can be used to generate orthophotos that vividly and precisely depict entire texture information (Napolitano & Glisic, 2018).

Computer-aided design (CAD) will facilitate the transfer of collected 2D and 3D data into a BIM model. Always, the processing of recorded building data necessitates a computer with a powerful graphics processing unit. Consequently, during the approach, a powerful graphics card and advanced CPU are preferred.

In order to better disseminate the digital heritage project, Virtual Reality (VR) is incorporated into the processed BIM model. With the assistance of numerous software platforms, VR headgear like Oculus Quest, Sony PlayStation VR, and Valve Index VR Kit may simply connect to a 3D scene. The VR user experience depends on both the performance of the computer and the capability of the VR gear. As the final platform for interactive information sharing and VR engagement, Unity and Unreal Engine are utilized in the examined scenarios.

	Hardware	Key Word	Character	Descrip
Laser Scan		Scan to BIM, Point cloud, Site survey,	Documentation	A laser into text the targ recorde
Photogrammetry		Photogrammet ry, Site survey,	Documentation	Photogr all the fa recogniz generat
CAD		Graphic card, Processing, BIM, 3D Modelling,	Documentation Representation, Dissemination	Comput capabili advanc efficienc
VR Connection		Virtual reality, Interpretation, Immersive,	Dissemination	VR hea by 360° commo applicat



Laser Scan

Photogrammetry

Fig16. Summary of technologies and

tion	Major Products
scanner is used to scan the real-world objects tured point clouds. Face the scanner in front of et building and the 3d information can be d precisely.	FOCUS 3D, RTC360 3D
rammetry is to photograph an object by covering aces. The photogrammetry software can ze the 3d relationships upon 2d images and e digital model.	Canon, Sony, Nikon, Panasonic
ter is the core of the digital approach. The ty can impact a lot on the processing time. An ed graphic card is preferred to improve cy.	AMD GPU, NVIDIA GPU
dset provides participant immersive experience panoramic view. The products are becoming n in recent years for its lower pricing and more tions with novel experience.	Oculus Quest, Sony PlayStation VR, Valve Index VR Kit

VR Connection

tools from researches (self drawing).

Project Objective

In chapter 1, both the theoretical and practical foundations of digital heritage are introduced. After extensive research and case studies, we are able to conclude our own concept and formulate a reasonable target for the field's future development. The expansion of the Internet and the increase in virtual activities in recent years indicate that digitization with a more immersive user experience is the trend. This indicates the direction of future growth and demand. From the reviews of literature and online cases, we can understand the meaning of digital heritage: to help recall the memory of our ancestors by reviving culture heritage from ashes, to preserve the story of our history by preserving the data via BIM and the internet, and to educate between generations by addressing the emotional sense of history. This allowed us to comprehend that the interpretation of digital heritage should emphasize the various contributions it made to society. Through the study of research articles, we gain a deeper understanding of the approach and procedures involved in practice. We are able to determine where the field's limitations lie and where additional progress can be made. The aims and workflow have established a benchmark for us.

In conclusion, at the end of chapter 1, the research purpose is defined as follows: scientifically replicate a heritage site with the same aesthetic (material authenticity, immersive environment). In the following chapter, we will apply the researched theory to the duplication of an Italian heritage site: Monza Park.

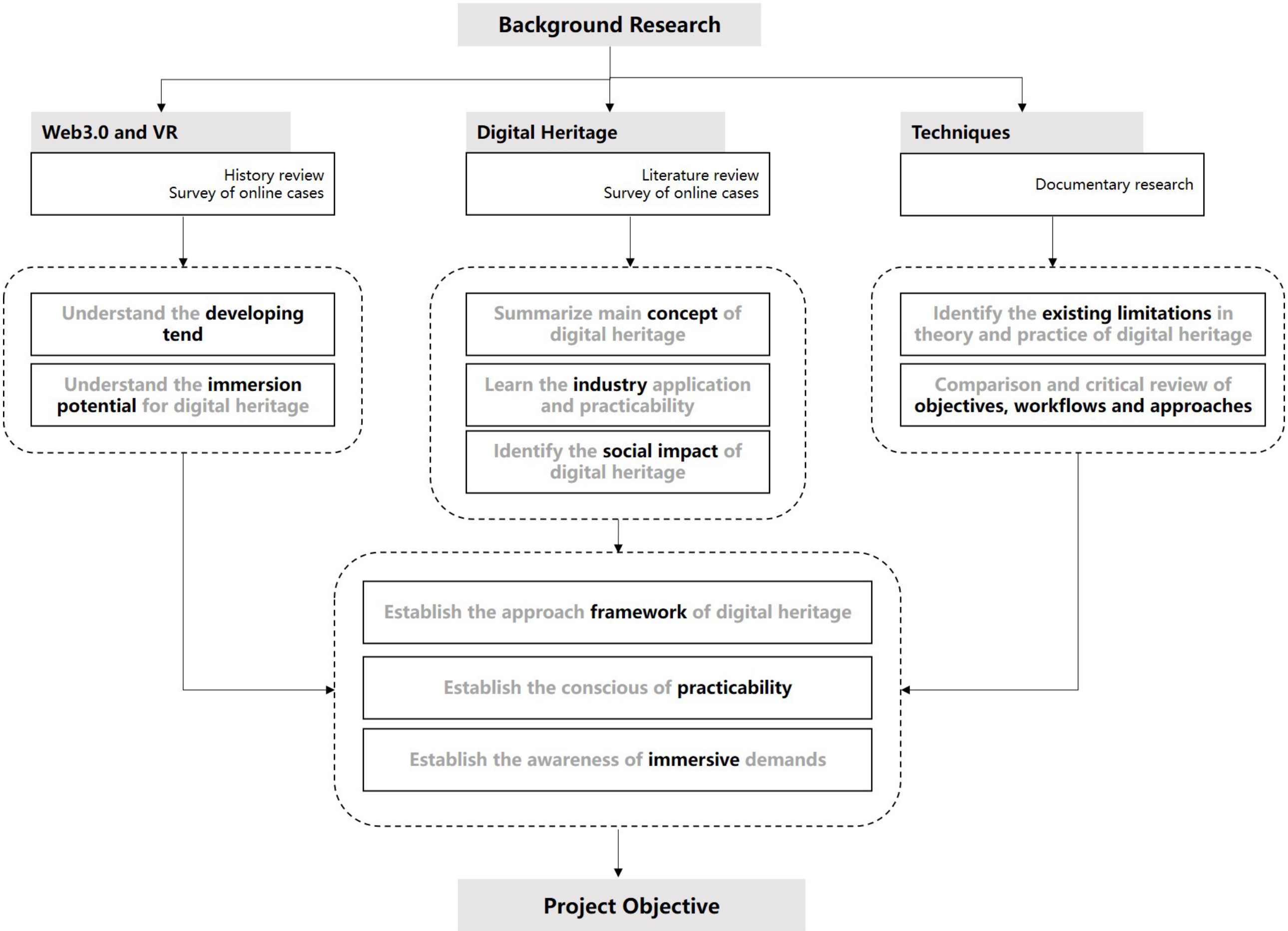


Fig17. Map of theoretical approach(self drawing).

Chapter2 **Monza Park**

General Context

Italy is a country with profound history along with the cultural heritages. As of 2021, Italy has 58 listed sites by United Nations Educational, Scientific and Cultural Organization (UNESCO), making it the state party with the most World Heritage Sites. Though Monza Park is not one of them, the historical buildings and landscape also tells the story of ups and downs(Wikipedia).

Monza park is a large walled park with a history of 200 years, the main part of which was completed as a delights place in 1808 for Napoleon's stepson Eugène de Beauharnais. It was the the backyard garden of his palace (the Royal Villa of Monza)during that time (French occupation of northern Italy). The hundreds of ground hectares area allowed royal family farmed and hunted in the park. The 13 kilometres long wall was built three years later, including an area of 732 hectares of the park . During the period from 1805 to 1899, Monza park was open to the public. Experts and passionate botanists enriched its landscape, and created a welcomed site for different activities. "The farm and wood wide area design, joining the Palace, was accomplished according to the landscape design of Luigi Canonica. In fact, the main architectures of farms and villas within the park area were adapted and transformed. Wide tree boulevards were established or reorganized, the ground was shaped and the water system was adapted to the new needs. Extraordinary views were opened to the most charming external and internal areas and to the "bosco bello" (charming wood), to the Lambro river, to farmsteads, to mills, to farming and hunting grounds." (Ms. A. Maniglio

Calcagno). In early 20th century, the park was private because it was owned by the Italian Crown. They didn’t open the public until the end of 1st world war, the royal family yielded up to the Italian government and left the park.Italian State then cedes it to Associazione Nazionale Combattenti (an Association for Italian war veterans), that in turn yields the full ensemble to a consortium formed by Monza and Milan Cities and Societa' Umanitaria. From1922 on, it was occupied by sports and leisure activities and established private clubs for economical benefits: 1922 motor-car racing track; 1923 horse racing track; 1928 golf course; 1930 tennis courses. And the activities also evolved with time. 20years later, the major events became hockey course, polo club, building housing the Italian broadcasting company, stables, camping, swimming pool, kennel, and golf course widening are accomplished (Bergamaschi, 1996).

Nowadays, most part of Monza park is open for public for social activities and daily leisure. Its large lawn was favorable in neighbourhood. Shadowed by trees with hundred years of age, the path in Monza Park always attracts jogging and biking activities. The citizens from neighbourhood also enjoy the park by taking walks and picnic in the park. Some of the buildings in Monza Park is stilled owned as private properties for horse training and living. In addition, the park has many agricultural facilities, mostly farmhouses. There are also three mills in the park (one is inhabited one is leased for agricultural use and the other is exclusively a monumental building). Although they have been abandoned for a long time, the characteristic features still imply the truly unique of the park. The park is lively today for its many visitors, those who come here to enjoy pleasant moments and relaxing for fun days, and most importantly by the groups of people who flock here (day after day, at any hour and in any

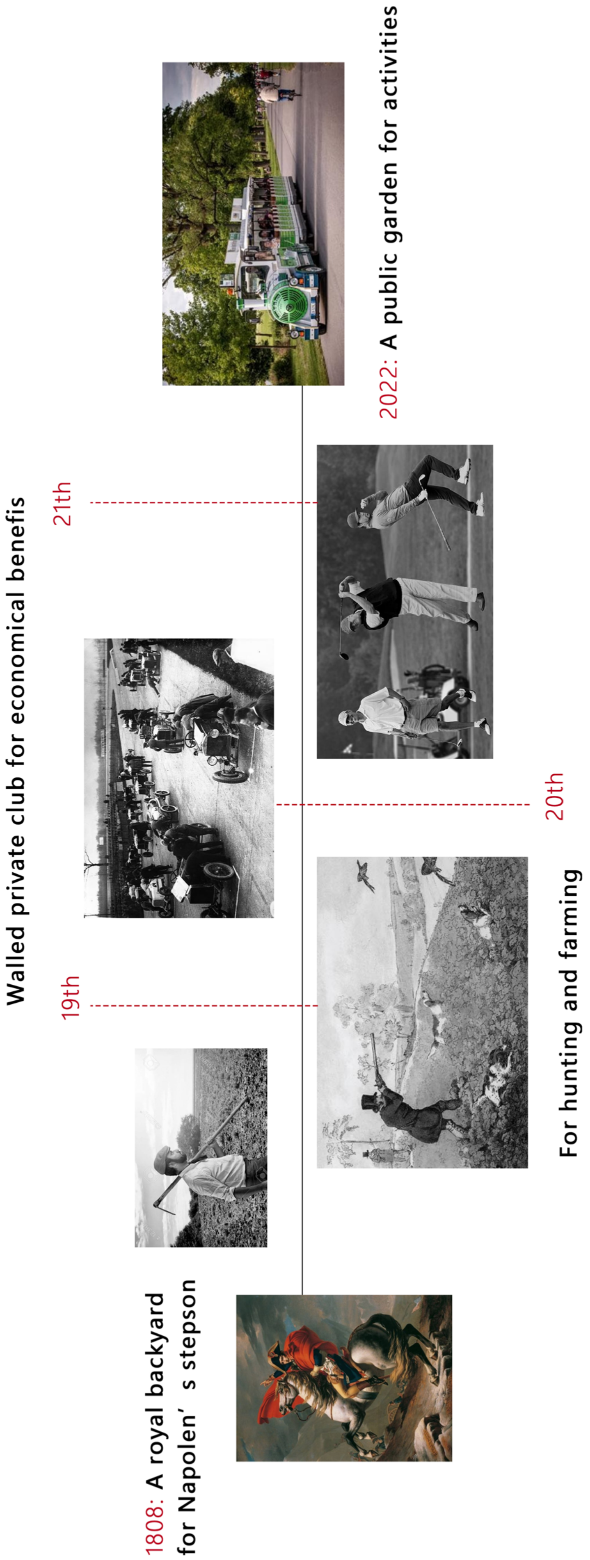


Fig18. History timeline of Monza Park (self drawing).

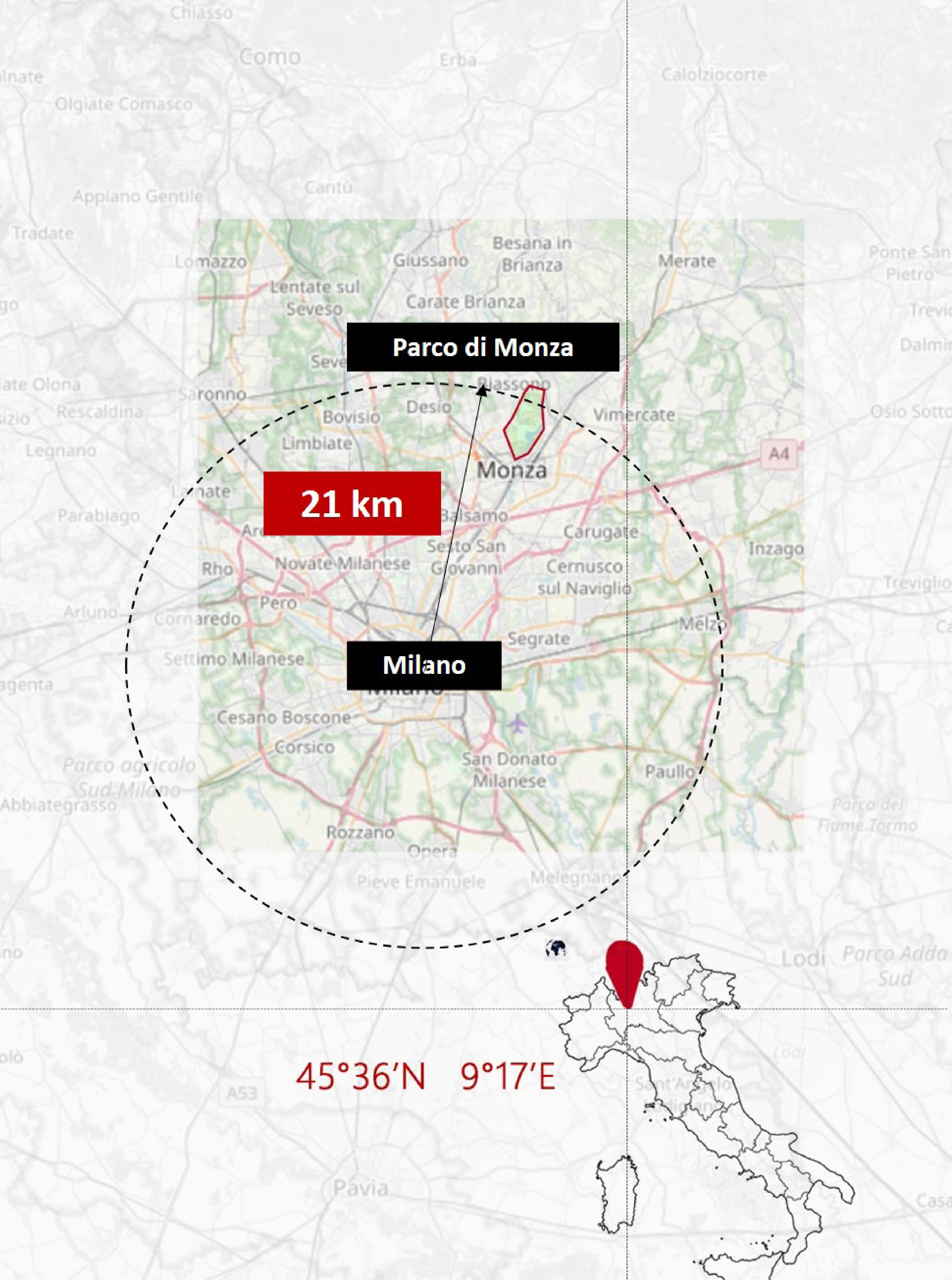


Fig19. Location of Monza Park (self drawins).

season) to exercise, alone or in small groups, resulting in the creation of the Sports in the Park project. There are five trails in the park to allow visitors to fully explore and discover the fun place for its fascinating secrets of nature and historical treasures. There are also stories about gnomes, knights and witches in the park being represented in statues and pictures to attract the curiosity of children.

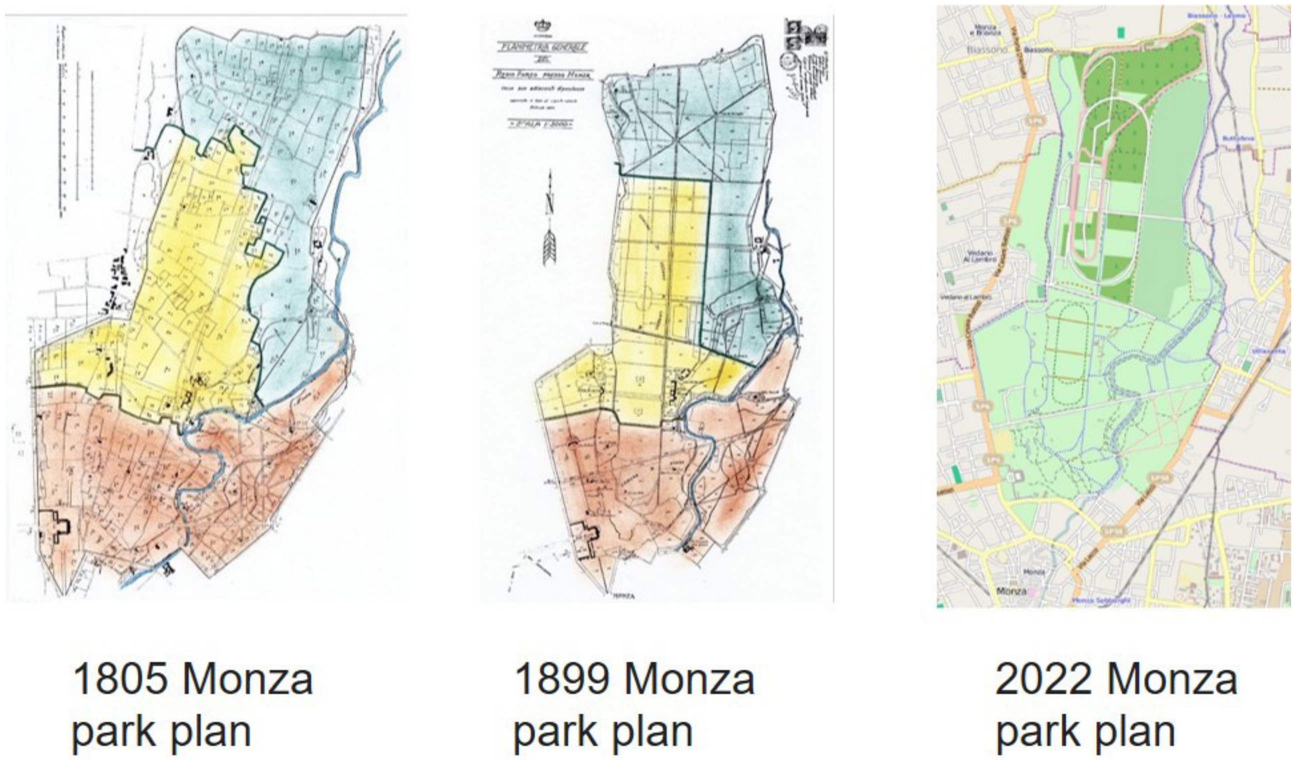


Fig20. Monza park plan history timeline(self drawing).

The Studied Heritage Site

We are going to concentrate on the most notable part of Monza Park, which is situated in the park's core, because it is physically impossible for us to chronicle every facet of the park due to its enormous size. The Mulino del Cantone, Villa Mirabello, and Cascina Casalta are the three most well-known buildings in the park, and they are all included in the UNESCO World Heritage Site. In this context, the term "Heritage Site" refers to a region that is significant for its cultural or historical significance and also includes the topography and flora of the surrounding area. The property comprises all of the traditional landscapes found in Monza Park, such as the vast grassland to the west of the main cement road, the deep trees with hidden paths that surround the mill, and the river that runs through the entire park.

The historic Villa Mirabello is undoubtedly the most eye-catching building in this region. The Villa Mirabello is the one that has been around the longest, and it can be found in the middle of Monza Park, right next to the equestrian school. In addition to its fame, the estate is known for its breathtaking surroundings. The historic home can be found along the Viale Mirabello, which is the primary thoroughfare that extends for two kilometers through the entire park. It is the most popular spot for strolling among all of the tourists. Visitors are able to have a sense of a great green area where they can relax, sunbathe, or roam in complete solitude thanks to the building's courtyard, which has an excellent visual link to the large green meadows that are located all around it. In addition to that, this property features a plethora of cultural

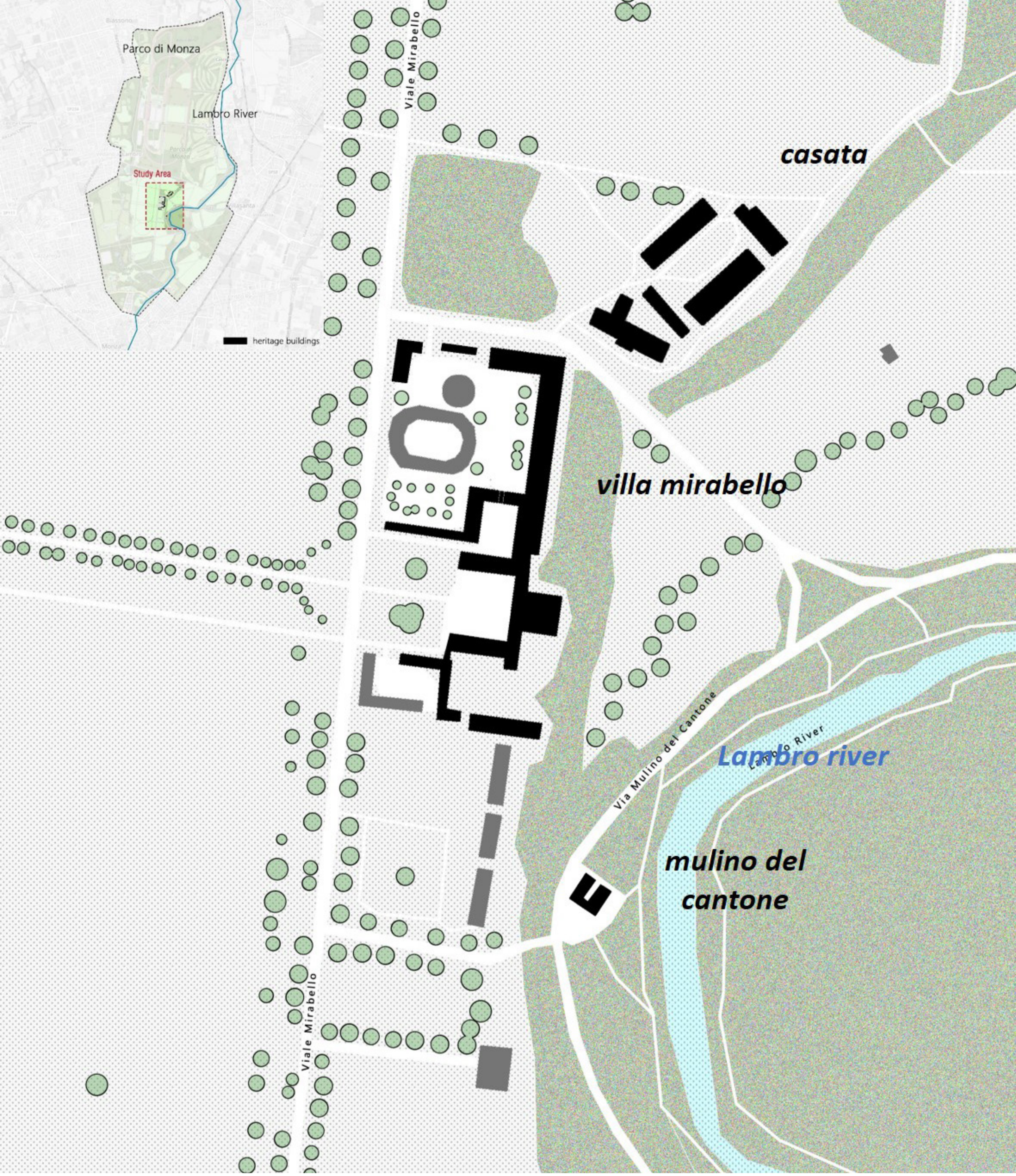


Fig21. Mapping of study area(self drawing).

exhibitions, some of which include theater, painting, sculpture, and other types of art. It is reported that this building underwent its most recent renovation in the year 2008. This lovely mansion in Monza Park has a lawn that is both quite expansive and very well shaded, which makes it a great location for hosting events such as parties and festivals.

Cascina Casalta, a farmhouse that dates back to the 19th century and is now used as a private residence, is located not too far to the north of the equestrian facility. It was designed in the neoclassical style and built between the years 1805 and 1825 by architect Luigi Canonica, who was assisted in the construction by Giacomo Tazzini. Near the close of the 19th century, Tarantola, who served as the court engineer, was the person primarily responsible for the extension. A rustic courtyard that looks out over the stables and barns serves as the design's focal point. The Cascina Casalta enjoys a privileged location in the middle of the Monza Park, among expansive meadows and wooded regions; yet, the worship of beauty and harmony has ceased, as indicated by abandoned recreational amenities and waste. The barrels and vehicles were placed and parked in a haphazard manner. Tourists, who are mostly elderly but friendly, have regular interactions with its locals, and these visitors are always pleasant. In terms of its surrounding environment, the position is in close proximity to both grass and horses, and the atmosphere is calm and beautiful.

The mill known as Mulino del Cantone can be found in the middle of the forest on the edge of a walkway. It was built in the middle of the nineteenth century to serve as the barracks for the Royal Carabinieri. Even if the building appears to be in decent condition from a distance, it is already in a severe state of abandonment, as seen by the extensive graffiti that is written on the walls, the overgrown weeds that surround it, and the broken doors and windows. It used to be a mill that had a distinct architecture. It was created by combining the remains of the earlier towers with symmetrical and neoclassical constructions that were built on top of them. The architectural design of the complex is predicated on the southern facade, which connects the two wings through the use of a portico that hides a millstone wheel that is carried by the river. The architecture of the complex is controlled by the architectural design. The conventional hem of the connection column is concealed by an ornate structure that has a round cutout in its center. Two circular windows with exposed brick frames finish out the composition of the building's facade. A distinct gallery appearance is created between the various building components thanks to the side beams with arches that allow the Lambro River to pass through. This effect corresponds to the mill locks. In contrast to the rest of the building, the tower is made entirely of exposed brick, and it ends in a merli ghibellini with a few small windows. This area, which was originally known as Molino dell'Angolo, has remained inaccessible for the better part of three decades. This factory, which has been the subject of a number of different restoration projects, is thought to be the only surviving piece of the ancient defense line that formerly protected Monza.

The heritage site in Monza Park is renowned not only for its historical significance but also for the outstanding architecture and the verdant surroundings that it features. It is a significant piece of historical heritage that possesses the potential for pedagogical, touristic, and academic applications. The researcher intends to study how digital tools may be utilized to reconstruct and show the cultural place with authenticity and engagement so that it can be preserved. This will allow the researcher to make the most of the gift. In the next chapters, we will conduct an analytical experiment and study on the workflows and methods utilized by the duplicating strategy.

Chapter3 **Workflow Design**

Visualization and Texture Mapping

Realistic visualization is mostly dependent on texture quality, and it is always a challenge to strike a compromise between quality and work pace. Having constructed a 3D model of Rhinoceros with empty material, the texturing strategy was intended to incorporate 2D information from the real world into the digital assets. Textures can provide material information for historic buildings and are a crucial component of the documentation strategy. Examining the most efficient approach to project 2D information onto 3D objects is the objective of the workflow. As described in chapter 1's objective, the purpose of the project is to give flavor. Thus, the purpose of the texturing approach is to attach 2D images to buildings as precisely and efficiently as possible.

The technique of 3D model texturing is nearly identical across the industry's 3D recreation tools. In addition, the principle is known as UV mapping. UV mapping is the process of superimposing 2D pictures as texture on an object at a specific scale and position. U and V are two orientations of a surface, and the map is a two-dimensional image storing texture data as pixels. Each three-dimensional block in a model can be viewed as one or more two-dimensional faces that can be unwrapped into a plane. Texturing is accomplished through the projection of image data onto these planes. By modifying the UV vectors, the density and direction of identically projected maps can be altered. UV Mapping is a laborious and time-consuming method that requires the gradual alignment and adjustment of surfaces using photographs. To match the complexity of materials in the actual world, there are numerous types of maps that provide information through various perspectives. For instance, to name three of the most common ones: the base color map (always regarded as the foundation map) offers surface color information, the normal map provides comprehensive height difference information, and the

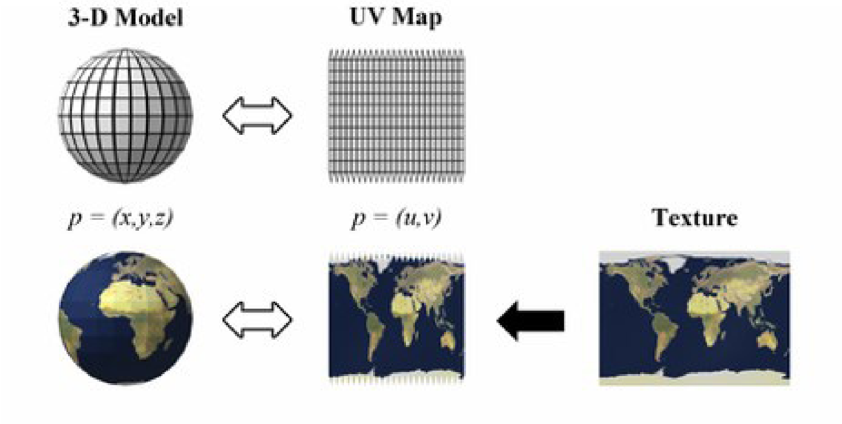


Fig22. UV mapping operation diagram (Wikipedia)

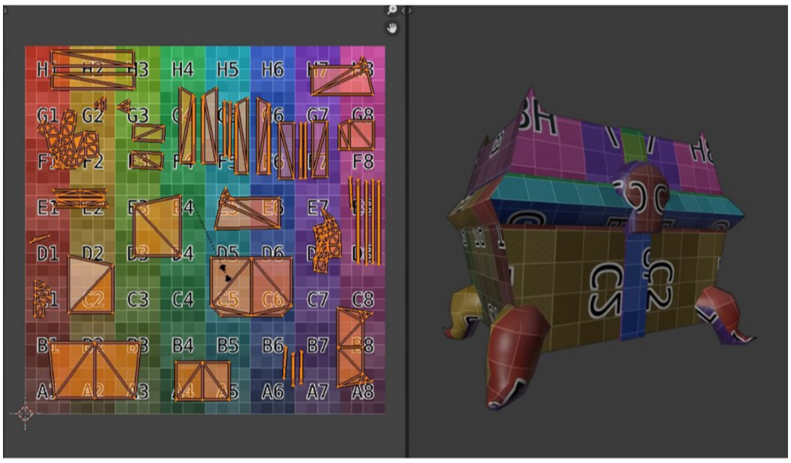


Fig23. UV mapping operation showcase (https://flippednormals.com/downloads/uv-mapping-for-games/)

altitude map provides altitude information. The roughness map indicates where and how much light is reflected by the map's areas. In UE5's material shader system, several material maps can function in tandem via blueprint. Because UV mapping is always performed manually and texture maps provide information, we can deduce that the efficiency of our job depends on the speed of UV mapping, while the quality of our final product is determined by the maps we employ.

The objective of texturing is to recreate the original model using realistic and precise materials. For the manually mapping procedure, however, labor speed would have to be sacrificed for quality. And it is not recommended to carry a model through several applications since problems can occur unpredictably due to software framework differences. When assessing and evaluating a workflow, we believe that the work time, output quality, and procedural simplicity are the three most important factors to consider. In order to establish a scientific digital legacy project, the purpose of the texture workflow must be to ensure the quality of the final product in a timely manner. In addition, the procedure should be as easy and straightforward as feasible in order to prevent unanticipated issues with model transfer and the cost of adapting new technologies. To achieve a practical and optimal procedure, we use quality, speed, and simplicity as three testing cafeterias.

Brief of Related Software

Rhinoceros3D 7 (Rhino7): Rhino7 is a 3D computer-aided design (CAD) program extensively used in the fields of industrial design, architectural design, and fashion design. It is compatible with both the Microsoft Windows operating system and the macOS. Rhinocerosceros geometry is based on the NURBS mathematical model, which focuses on developing mathematically correct curve representations. The advantage of NURBS surface (as compared to polygon mesh) is its greater freedom for computer graphics with absolute accuracy, which is commonly utilized in the digital scan sector to build more precise models. The variety of modeling options enhances Rhinocerosceros's modeling speed for both simple and complex geometries. Additionally, Grasshopper is a robust add-on for Rhinoceros that enables visual scripting language. Users do not require coding skills to operate the plugin, thanks to its blueprint and nodes-based interface. In addition, there are numerous programmed templates for certain functions that may be found online, mostly in its largest community Food4Rhinoceros. By modifying only a few variables, this template may accomplish complex tasks, such as the transformation of a point cloud into geometry.

Agisoft Metashape(Metashape): Metashape is one of the most prominent software products utilized in cultural heritage documentation, visual effects production, and geographic information systems. It is distinguished by its capacity to generate 3D spatial data using image photogrammetric processing. As a result of its capabilities, it can also do indirect measurements on objects of various sizes. The software permits the processing of images from RGB or multi-spectral cameras, including multi-camera systems, into high-value spatial data in the form of dense point clouds, textured polygonal models, georeferenced genuine orthomosaics, and DSMs/DTMs. Further post-processing makes it possible to erase shadows and texture artifacts from models, calculate vegetation indices and extract data for agricultural equipment action maps, automatically classify dense point clouds, and so on.

Blender3.0(Blender)

Blender is a free, open-source program with a small file size that is very easy to download and use. It is one of the most recommended 3D modeling and texturing applications for novices among all 3D recreation lessons. It is mostly employed in the video game and film industries due to its potent modeling, texturing, and animation capabilities, as well as its interoperability and interactivity with numerous other 3D computer graphics programs, such as Rhinoceros7 and UE5. Blender's interface is incredibly intuitive, with a tiled panel on top and numerous sub-layer windows below. One platform window (typically enlarged to fill the screen) is divided into parts and subsections of any Blender view or window type. With the coexistence of many windows, it is easier to preview the creative process, particularly the UV mapping of texture technique. With these capabilities, Blender becomes an effective tool for manipulating 3D models with textures.

Unreal Engine5 (UE5)

Epic Games has recently published Unreal Engine 5, an evolutionary piece of software. It was believed to be the future of the digital recreation industry and was shortly followed by a

$2 billion investment from Sony and the Lego family. Parallel to Unity 3D, UE5 captures half of the video game production business, with extra possibilities in filmmaking and architecture rendering. Unreal Engine was selected as the final representation platform for numerous digital heritage projects due to its integration capabilities and realistic real-time rendering. The blueprint concept permits users to develop programmed functions without coding. Lumen Global Illumination (it can bounce diffuse infinitely from all surfaces to bring the digital scene closer to reality) and Nanite Visualized Geometry (it allows for geometry to be much more detailed and realistic in face by computing with much lower resolution in distance and background) can allow a laptop to perform real-time rendering in a large, detailed environment with less demand on the computer's processing power.

Software	Major Industry	Function Used for Project
RHINOCEROS	Product Design, Architecture Design.	**NURBs Modeling** **UV Mapping**
METASHAPE	3D Reconstruction, Visualization, Surveying and Map- ping.	**Photogrammetry**
BLENDER	Fim Production, Video Game.	**UV Mapping** **Polygon Modeling**
UNREAL ENGINE	Video Game, Fim Production, Architecture Visual- ization.	**Environment Recreation** **Material Setting** **VR Representaion**

Fig24. The software and their tools applied in the project (self drawing).

Workflow1: Blend Material in UE5

Material editing in UE5 is the workflow with the least complexity. Since UE5 is the final platform for representation, the visual effect may be identified and assessed in the simplest manner. In addition, UE5 features its own material application system, which eliminates the need for numerous program transfers to get a textured 3D model. Blend material is one of the most effective tools in UE4 for creating realistic textures. Blend material is a functional substance that can contain multiple materials (such as brick, mud, and grass) simultaneously. They are superimposed in the form of layers, allowing the user to paint or erase. To match the richness of the real world's textures, one can paint through a variety of mediums (brick covered by mud, etc). The extensive material collection within Unreal Engine allows for a variety of options to achieve resemblance. All of these elements are sourced via picture scanning in the real world, and their realism is firmly assured. To use this principle, we adopted the following strategies:

1.In Rhinoceros, manually distinguish the material and arrange objects with the same material into the same layer. Attaching distinct materials to distinct layers allows items having the same material in the real world to have the same material in Rhinoceros.

2.Transfer a model in fbx file from Rhino to UE5 with the greatest possible mesh quality. Examine Quixel (a big free 3D asset collection that collaborates with UE) and select materials that are similar to the building's texture parts. And blend the textures using the blend material plugin using the selected textures as blend material.

3.Apply blended material to appropriate surfaces (objects) and paint in layers to represent the complexity of textures. To ensure accuracy, the procedure was conducted with continued reference to site photographs. Painting is a manual, time-consuming operation. We attempted the approach on only one height in the Cascina Casalta, and it took thirty minutes. It may be anticipated that it would take countless hours to manually apply blend material to each and every surface.

Comment:
First, the likeness is limited because the source material is an internet library rather than a site photograph. Second, certain essential building information cannot be conveyed, such as the arch-aligned bricks above the window and the varying directions of the timber bars on the door (though it can be fixed by adding complicity with more software and approaches involved, it has over-passed our discussion range). In conclusion, the loss of data is unsatisfactory for the project. This goes against the purpose of heritage documentation.

As predicted from the trial of a single façade, the time cost for the full project may be incalculable. In this manner, surface would be manually rebuilt (paint through various material channels) using the site photograph as a guide. It is more appropriate to buildings with countable little volumes than it is to large structures.

Simplicity: The procedure is as straightforward and transparent. This is the most effective method for avoiding unknown format-related difficulties during file transfer.

Using the blend material(from libraries) tool in UE5 to create a realistic mixed texture is the first workflow. Although the conclusion can attain a similar flavor, a great deal of architectural information was lost. In light of the project's scientific and realistic duplicating purpose, the loss of building information violated the originality principle. Consequently, in the subsequent phase, the author investigated the feasibility of duplicating the material information on 3D models directly from site photographs.

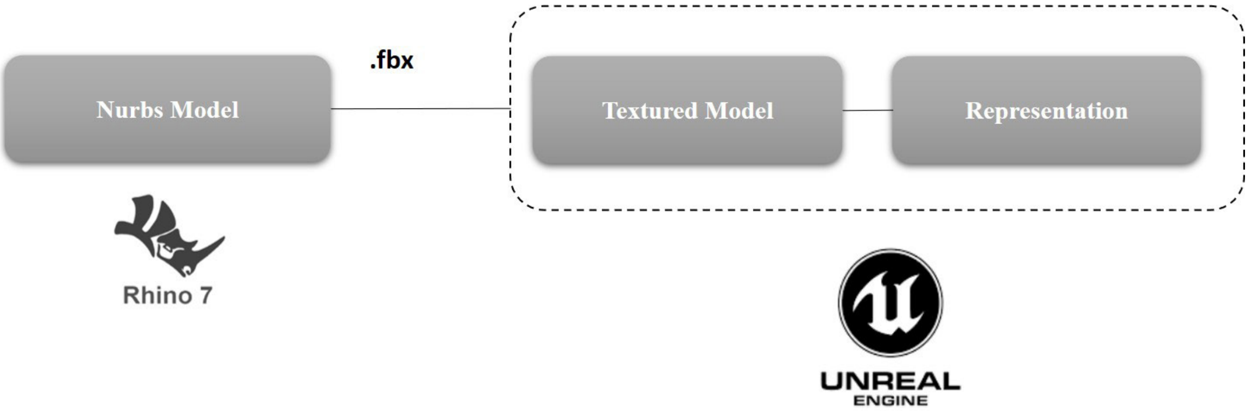


Fig25. Approach diagram of workflow1(self drawing).

Fig26. Lost of information in workflow1(self drawing).

Workflow2: Map Orthophotos in Rhinoceros 7

Instead of eploying a material library, scanned orthophotos of building surfaces can transfer real-world texture information into digital formats. In the meantime, the information from photographs can attain the highest degree of precision and realism compared to online resource libraries. Considering the "similar taste" objective, the technique to obtain superior quality is to use the photo as a modeling material. First, we can explore utilizing Metashape to arrange site photographs into orthophotos, which can subsequently be mapped into the Rhinoceros 3D model. The procedures are as follows:

1.Obtain Orthophotos as maps from Metashape. The approach is based on the generation of a 3D textured model from the site's numerous photographs, followed by the output of orthophotos from the model. The orthophotos can then be processed and altered in Photoshop to produce texture maps with higher quality.

2.Using Rhinoceros to map an Orthophoto to a 3D model. In this stage, we can construct a material from an image using the previously prepared texture maps and then UV map each object in Rhinoceros7. The UV mapping technique is the most time-consuming aspect of the project because each structure has numerous faces and there are numerous buildings to be textured. In addition, the UV mapping tool in Rhinoceros7 is not straightforward to use; to elaborate, a plane must be constructed for every object to be mapped. The approach requires too many steps, and the time required for these procedures may be excessive. As is the case with the workflow1, we map only a single facade of a building in Cascina Casalta, which takes around five minutes.

3.Export the textured model as a Fbx file and incorporate it into UE5 content. Ensure that the greatest detail level is selected when the Rhinoceros transfer options bar appears. Create a folder for building models in the UE5 content browser. The import procedure takes three to five minutes per model, thus it is preferable to prepare the model at once to prevent wasting time.

Comment:
The outcome successfully conveys the flavor of a historic building. Textures of the highest quality allow the buildings to be expressed in the best way possible. The outcome can satisfy the project's requirements. The UV mapping process is time-consuming. First, while the UV Mapping application in Rhinoceros7 can accomplish the objective of casting orthophotos onto models, each unwrapped surface requires a strategy to attach the surface UVs. Second, the model preview cannot be updated simultaneously with UV node movement. The technique is also straightforward and unambiguous. The model and texture are both created in Rhinoceros7 to reduce job complexity.

Workflow2 is the Rhinoceros mapping of the orthophoto. In contrast to workflow1, the texture can preserve its greatest realism in accordance with the real world. However, it is also evident that the Rhinoceros mapping tool is insufficient for operation, as the time required for buildings with hundreds of faces would be immense. Thus, we seek a method with more effective mapping functions.

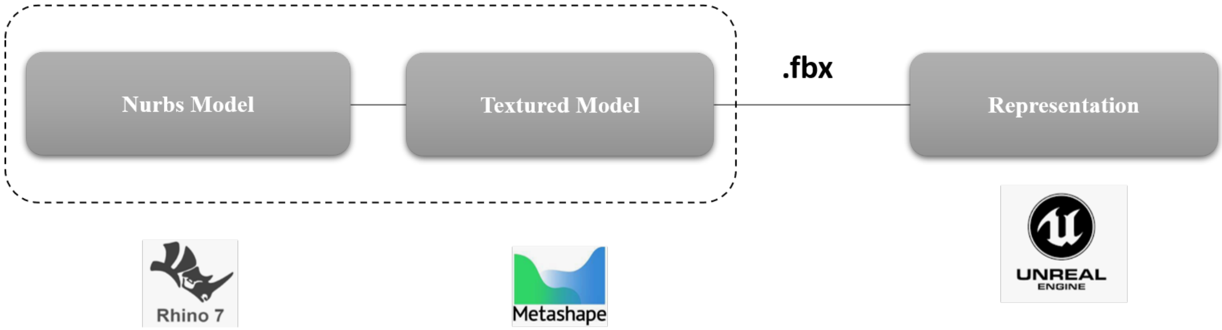


Fig27. Approach diagram of workflow2(self drawins).

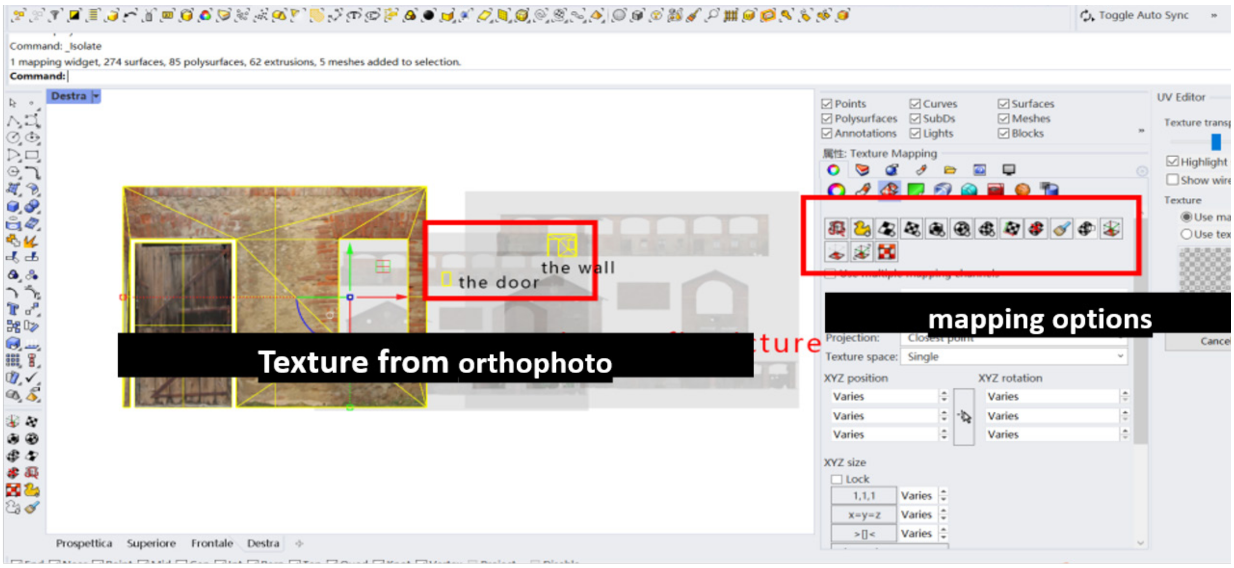


Fig28. Comlex mapping tool in Rhino7(self drawins).

Workflow3: Map Orthophotos in Blender

Since UV Mapping consumes the most time in the processing, it would be possible to significantly accelerate the texturing process by employing more efficient tools. Blender, a well-known 3D gaming application in the game and film industries, is renowned for its UV mapping feature. The tool is split as a separate area in Blender's toolbars, with customizable UV unwrapping options. Using this advantage, blender can be incorporated into the workflow to increase the speed of mapping. The work strategy is segmented as follows:

1.Obtain Orthophotos (camera scanning) from Metashape as maps. This is identical to workflow2, which documents the real-world texture information.

2.UV Mapping Blender objects In this stage, the 3D model is exported from Rhino 7 to Blender in obj format. The advantage of obj format over fbx is that material information is automatically deleted, resulting in a cleaner model. Blender's UV mapping is faster and more user-friendly due to a number of factors. The UV mapping procedure can be divided into three steps: unwrap (extend the UV map), mapping (adjust the control points on the expanded UV maps to fit the texture), and face direction check (to avoid error lighting calculation when rendered). First, the unwrapping bar offers more options than Rhinoceros, including the most popular "unwrap from view" option. Second, the visual comprehension of the texture impact is enhanced for the simultaneous window of UV mapping and 3D perspective. In comparison to manual procedures in Rhinoceros7, every step may be performed with a simple combination of keyboard shortcuts, such as "u" for unwrap, "tab" for UV mapping in Edit Mode, and "g" for move, to mention a few.

3.Export the model in fbx file to UE5. This method is identical to the workflow2 method, but it exports the model from Blender. The export settings are simple to configure, and we can leave everything as-is.

Comment:
Using images from the site allows for the most accurate presentation of the content. The precision and visual impression can satisfy the scientific and realistic objectives.Blender's UV Mapping Tool is a separate component that provides for more adaptable features to boost mapping's efficiency. For the numerous objects in the project, significant time savings are possible. We consider using Blender for UV mapping to be an improvement over mapping in Rhinoceros7 in workflow2. Although Blender is included as a third software during the process, simplicity is maintained. The complexity of file transmission does not result in an error. Neither does it take longer.

The workflow3 adds Blender as a third mapping application. Blender can save a substantial amount of time when mapping the orthophto compared to Rhinoceros in workflow2. In workflow3, project quality, time efficiency, and workflow simplicity achieve a harmonious equilibrium. With continued practice, this workflow's proficiency can be enhanced.

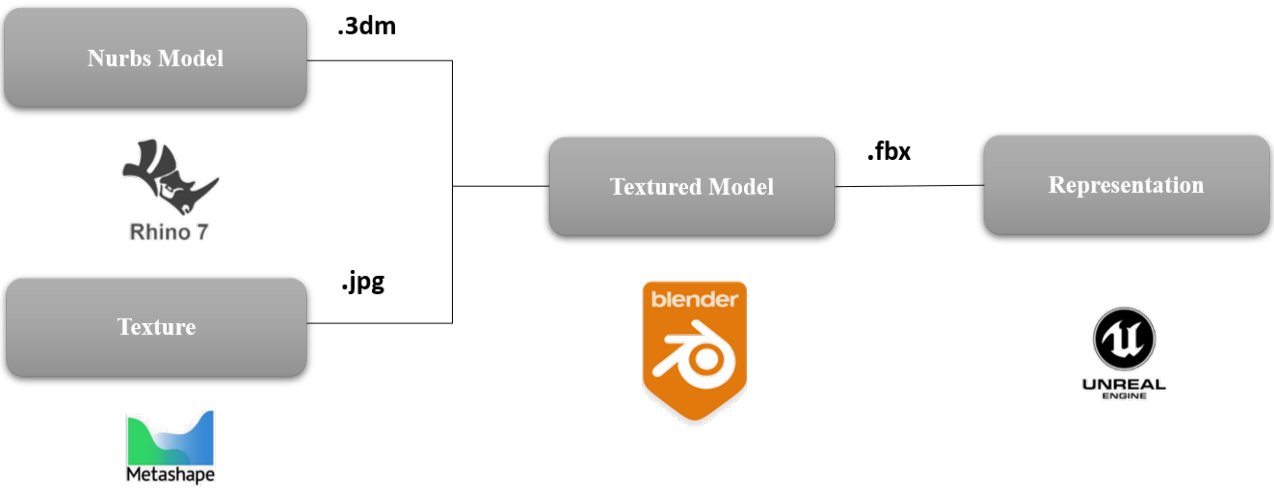


Fig29. Approach diagram of workflow3(self drawins).

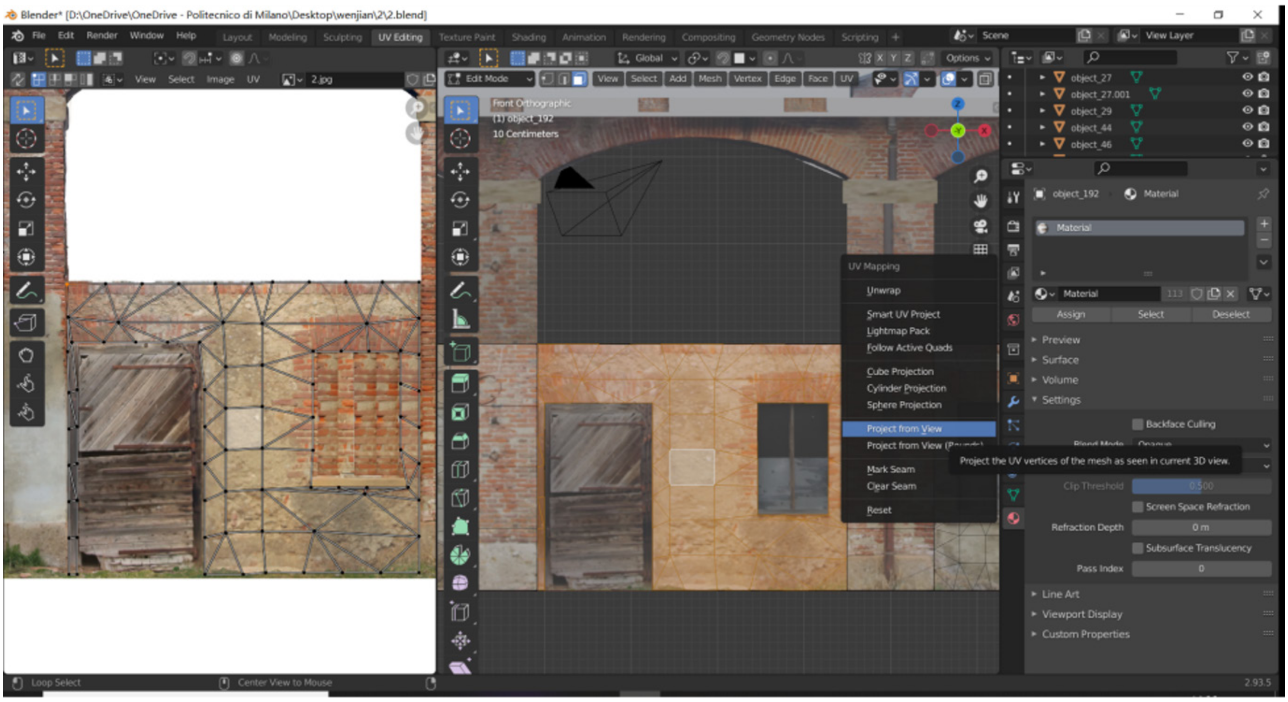


Fig30. Powerful mapping tool in Blender (self drawing).

Comparison and Optimization of Workflow

Each of the three workflows has both benefits and drawbacks. The workflow1 is the simplest because it requires the least amount of software and methods. When editing content, the final result could be presented immediately on the UE5 VR platform. Due to the limited ability to communicate material information, a great deal of structure-specific information was lost. Therefore, it cannot achieve the project's scientific purpose. As the material of the model in workflow2 was derived from real-world photographs, the scientific validity of the data could be assured. Rhinoceros7's material assignment tools are inefficient, despite the high number of volumes to be mapped for this project. Therefore, under the assumption of assessing job efficiency, we continue to see this workflow negatively. Blender, a professional material mapping application, was utilized in workflow3 to streamline the material mapping process and increase job productivity. Workflow3 not only ensures the authenticity and precision of material representation, but also minimizes the amount of time spent working. As a consequence of the comparison, workflow3 was chosen as the texturing solution.

Blender was used throughout the entire production to create accurate and realistic building models by combining the 3D data generated from a laser scan with the material data collected from photogrammetry.

After testing numerous options, the final workflow is an optimized strategy. The objective is to convert the physical heritage into digital formats as efficiently and precisely as feasible. In workflow3, we first generate an accurate 3D NURBs model using laser scanning, followed by an orthophoto with texturing using photogrammetry. Then, the blender mapping tool enables us to map the created orthophto onto the 3D model efficiently and swiftly. With the textured model, we can export it to UE5 as a fbx file in order to continue work (interactive design, VR engagement).

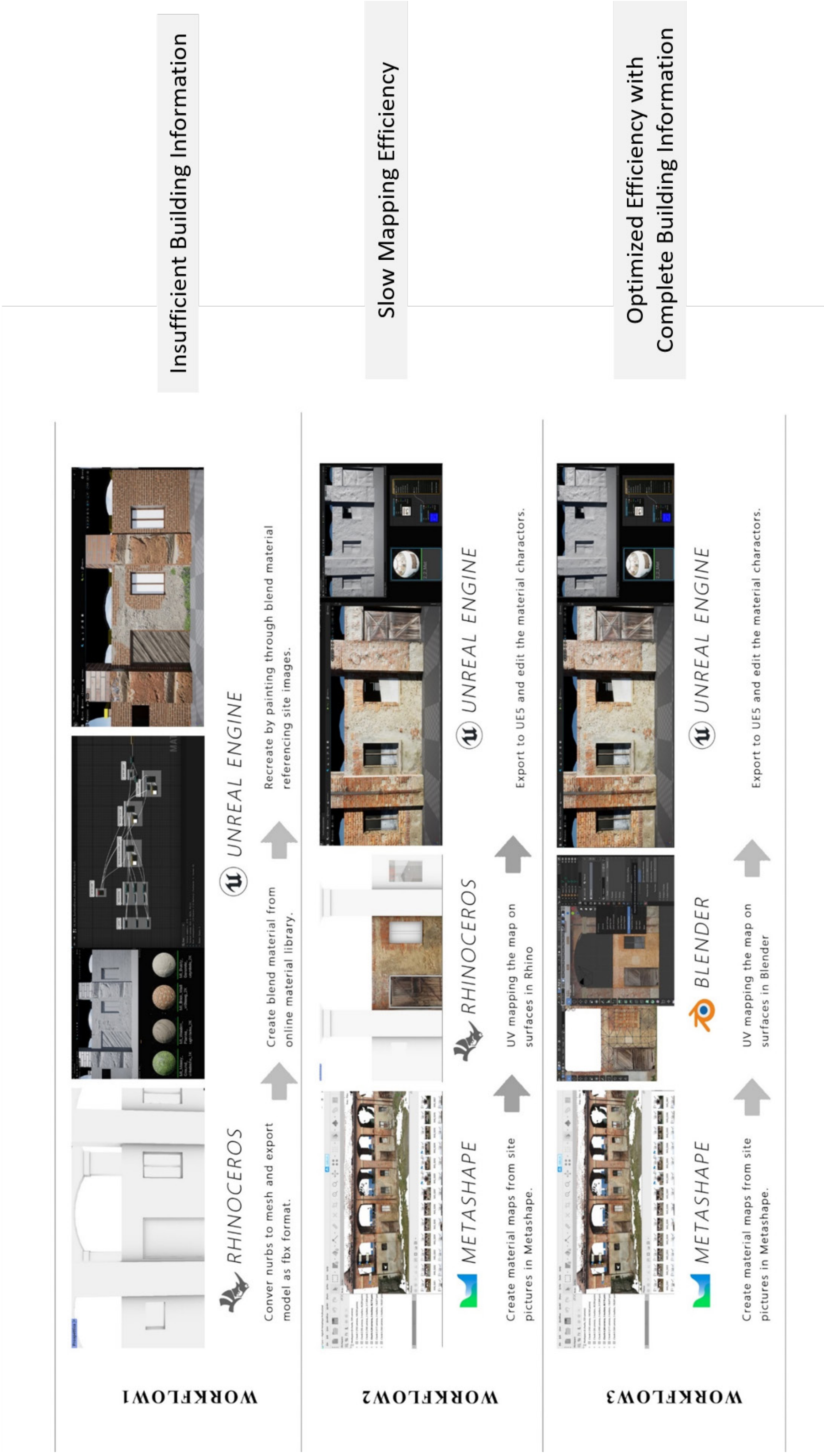


Fig31. Comparison of 3 workflows(self drawing).

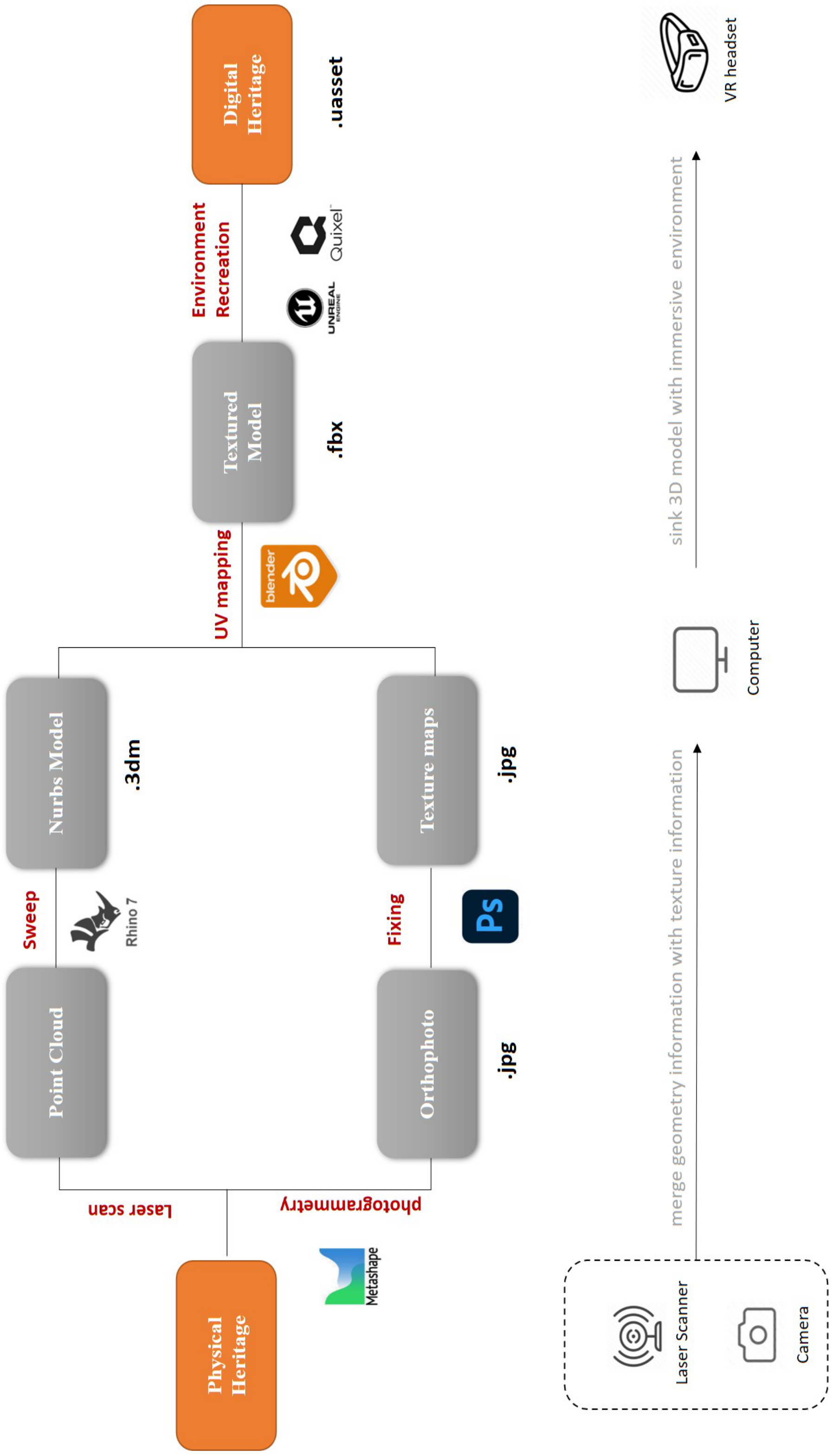


Fig32. Optimized workflow for the project(self drawing).

Chapter4 **Approach**

Site Survey

The process of digital duplication starts with the first step, which is to familiarize oneself with the location. In order to set up the documentation plan, particularly the 3D survey method, it is necessary to have an understanding of the physical condition, with a focus on the material features and environment components. The objective of this method is to do this. If we look at a map online, we might be able to identify that the place is a group of historic buildings that are situated close to the middle of Monza Park before we go there. It is comprised of a variety of buildings, each designed to serve a certain purpose, such as a mill, residential homes, and stables. There isn't any significant damage to any of them. The majority of the surrounding land is covered with grass, but the forest, with its clump of tall trees, seems to have been there by accident. In this scenario, it is plausible to assume that factors such as private requirements and natural constraints contribute to the inaccessibility of structures. As a result, a visit to the location in question is necessary in order to formulate a plan that is appropriate to digital surveying. The purpose of the site survey is to achieve a deeper comprehension of the accessibility, characteristics, and conditions of the surrounding environment. When conducting the survey, the following important questions were kept in mind: which qualities and attributes of the site are worthy of being documented and represented, and how can the information be digitally captured in the most realistic and scientific manner?

An accessible mapping tour was carried out to document the

Fig33. Accessibility of the study area (self drawing)

information-blocked area in order to ascertain the level of accessibility that exists within the research location, particularly in the area surrounding the structures that were examined. Even though the mobility infrastructure on the site, which includes a walkway and a road, has been completed, not all of the building volume can be accessed. To begin, there was an abundance of tall trees and bushes that obscured the view of the building facades from the camera. This was because the area was so natural. Second, the fences kept people from entering areas that were restricted to residents only. The enormous fence that surrounding Mirabello in order to keep tourists away was a barrier for the photogrammetry research that was being done. According to the findings of the research, Mirabello possesses a sizable and secure

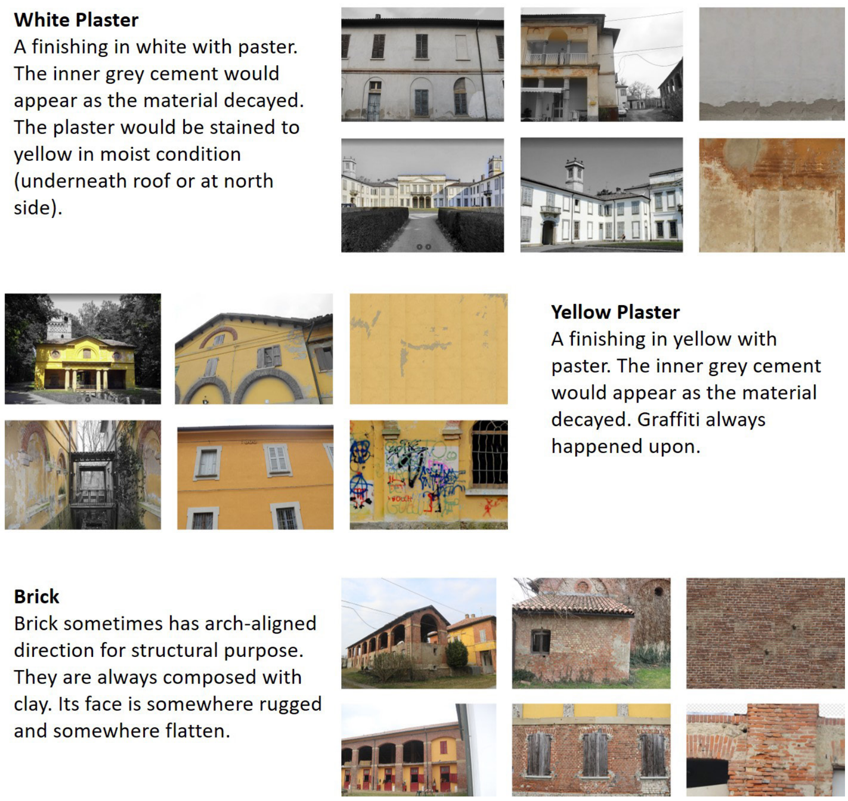


Fig34. Recognization of typical material features (self drawing)

private area. One of the private courtyards might be used for riding horses, while the other could be used for storing personal belongings. In addition to this, the majority of the area beyond Mirabello was hidden by trees, making it difficult to access on foot. It was impossible to take photographs in the mill's interior courtyard due to the restricted amount of room. The Cascina Casalta building, which was surrounded by wide space and had few trees, was the structure that had the facades that were easiest to approach. Using an availability analysis, the following photogrammetry method collected the facades. Facades that have been photographed are indicated by the red outlines, while those that have not been photographed are indicated by the blue outlines. It is possible to visualize the 2D information complexity of each building based on how they are depicted on the map. As is indicated on the right side of the map, in order to transfer the information that was most prominent at the site to the digital record, the author chose the perspectives that are most frequently

Fig35. Recognization of environment features (self drawing)

encountered by visitors when they are within each structure. The Cascina Casalta keeps the image of its yard entry, which is characterized by the simultaneous appearance of various building volumes made of a variety of materials and ranging in scale. The front facade of the Mill is embellished with a partially overhead ground level that is supported by classical Rome columns and has a design that is symmetrical. The symmetrical architectural arrangement of the Mirabello, as well as the expansive garden, which is one of the most popular visiting places, are two of the hotel's defining characteristics. The documentation of Cascina Casalta is the most extensive, in contrast to the documentation of Mirabello and the Mill, both of which have substantial portions of their courtyard sides that are not photographed and are entirely unrecorded.

The site survey also makes a contribution to the digital documentation of the texture. During the site survey, observations of building materials focus on their physical qualities, such as degradation, roughness, changes in texture, and situations. In addition, scenarios are taken into consideration. Brick, white plaster, and yellow plaster were the three principal building materials that the author noted as being utilized in the project. Both the Villa Mirabello and the Casata make considerable use of white plaster as a wall finish. On these surfaces, invariably, the inner grey cement of ruined material can be seen. The presence of moisture causes the plaster surface to turn yellow in some gloomy and rain-washed places, which can be identified by the appearance of the surface. Plaster of yellow color is used in the construction of many buildings in Italy. In a similar manner, the inner grey cement of decomposing materials is always visible. The plaster at the Mill has been vandalized severely as a result of the extensive usage of colorful graffiti on the building's facade. Brickwork that is one hundred years old was used in the construction of the site's stables in their entirety. Bricks are arranged in a variety of ways and kept together with lime in order to provide the desired structural effect. Because of the wind and ice, the bricks have become highly weathered and rough. Moss is able to thrive in these challenging environments, and it has partially covered the surface with a covering of dark green.

Fig36. Recognization of plant species (self drawing)

In summary, the environmental aspect of the site study was purposefully emphasized, and the topography and flora were subjected to minutely scrutinized observation. The goal is to acquire a comprehensive understanding of the location in order to digitally replicate it while preserving the same feel. During this inspection of the property, we took photographs of a variety of plants and the surrounding surroundings. As a result of the park's varied topography, guests were immersed in an elegant atmosphere during their time there. The impression that was given was that the collage was depicting the terrain and its environs in an abstract manner. Re-creating virtual species with the same breeds and sizes as the original ones is important for ensuring the authenticity of the area. As a consequence of this, while we are doing the process of site surveying, we will be use the mobile application PlantNet to identify the trees. Breeds are able to be identified from images that were taken on location thanks to the application. In addition to oak, birch, and maple trees, there are other flora that look like daisies and ivy that are native to England. As a result of the impossibility of assigning a mathematical value to the number of plants, we make use of the word "ar" to depict the various percentages that make up these plants.

From Laser Scan to 3D Model

(This approach was not conducted by the author, but from the research team by Professor Cecilia Maria Bolognesi. The author obtained the point clouds data and NURBs model without any participation. The following narrative is more about a rough introduction rather than a docunmentary record.)

Laser scan is a common tool to conduct the 3D survey in the field of digital heritage. Thanks to the developed sensing and simulation technology, the laser scanner nowadays has been much smaller to be portable during the practice. In order to obtain the 3D information of the heritage building, we document the buildings of mill, Cascina Casalta and Mirabello by laser scan. The scanning equipment we used is Leica RTC360 3D Laser Scanner. It can measuring rate of up to 2 million points per second at 6mm @ 10 m resolution. The laser scan to accurate 3D model can realize the documentation of 3D physical information.

Fig37. Leica RTC360 3D Laser Scanner (https://leica-geosystems.com/en-gb/products/laser-scanners/scanners/leica-rtc360)

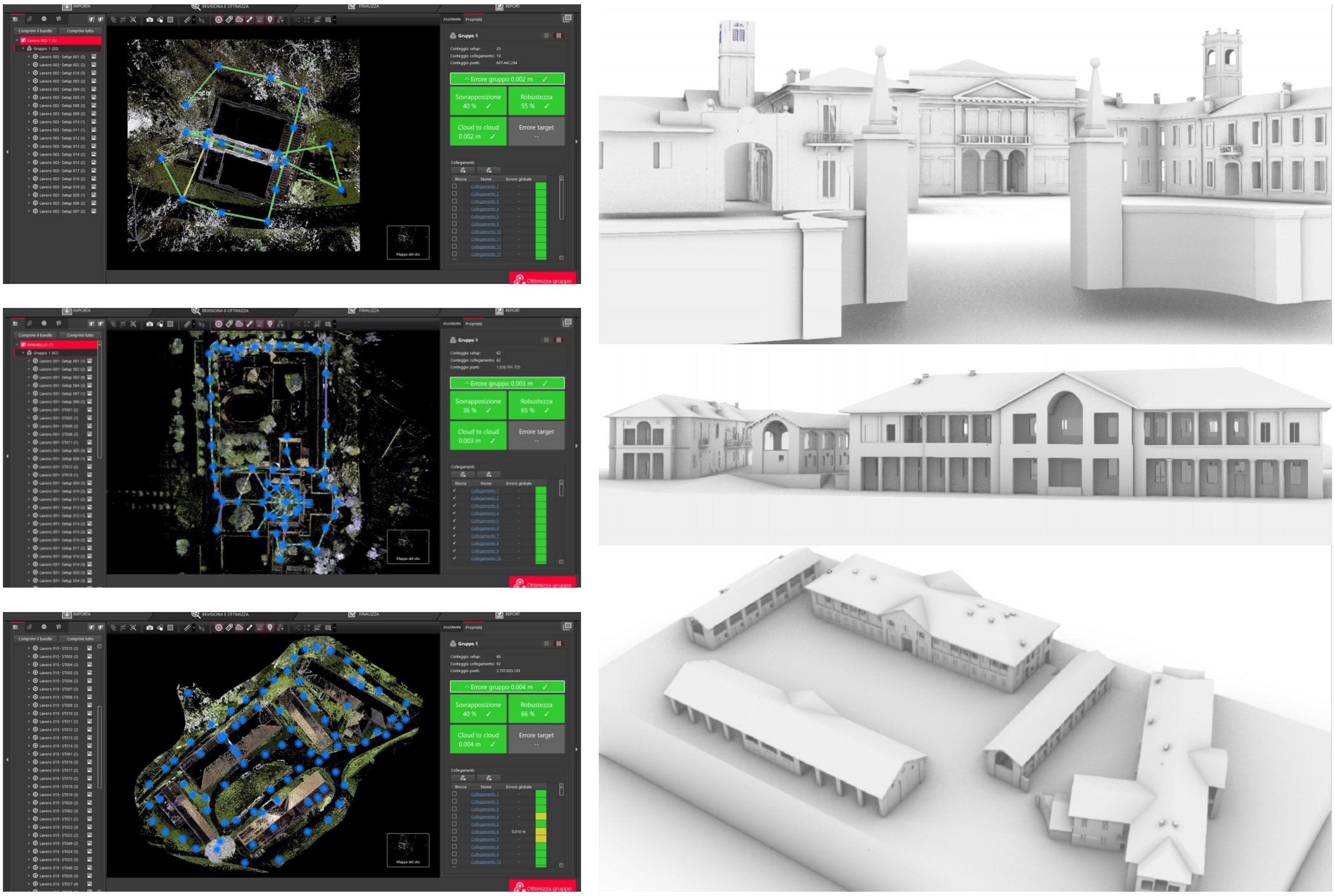


Fig38. From point clouds to Rhino7 NURBs model: Mill, Mirabello and Casata (self drawing)

It is commonly used to transfer real-world architectural 3D information into digital ones. Its work principle is to obtain the position information of the object by calculating the time of ray reflection to each surface. The data can then be recorded in the form of point clouds. In order to record the building information completely, each building needs to be scanned from many directions. The location of the blue bubble as shown in the figure is the location of the scanner each time it is scanned. After obtaining the scanned point cloud, we use Cyclon Register 360 to process the model and export the model in mesh form to Rhinoceros 7. Rhinoceros is a software for generating logic based on NURBs surfaces. The advantage of the NURBs surface is its accuracy relative to the mesh surface. In Rhinoceros, we finally get an accurate NURBs surface model by sectioning and rebuilding the mesh at fine intervals. Meanwhile, the entire workflow is a time consumption job and requires physical effort. Because the processing of point clouds needs dozens of minutes to wait on each scanning points, the whole process can take a whole day. At the same time, the selection of locations and fixation is always difficult because of the complex condition of the site(like vegetation, steep terrain, etc.) As a result, it requires a tacit team collaboration to finish the work.

From Photogrammetry to Texture Maps

In this procedure, the material data is extracted from the site photograph. The site photograph can be used to perform photogrammetry and generate orthophotos that can be processed in Photoshop as jpg files. The 3D model was formatted and mapped. Metashape (to create orthophotos) and Photoshop are utilized at this stage (to process orthophotos into texture maps). And the hardware requirements are a computer with enhanced image performance (which can reduce the metashape photogrammetry processing time) and a camera.

Many areas of the site are frequently inaccessible due to the obstruction of plants. Thus, we were unable to photograph every building surface. Therefore, the goal of this procedure is to record as much material information about the building surface

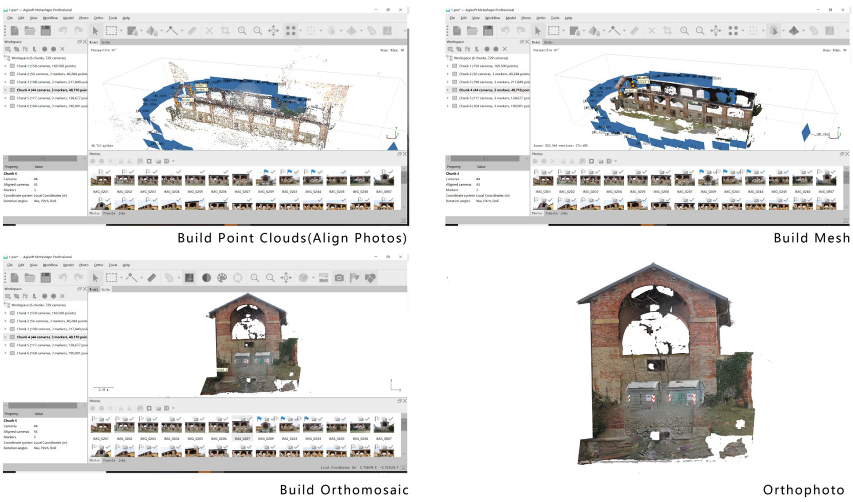


Fig39. The photogrammetry operational steps in Metashape(self drawing)

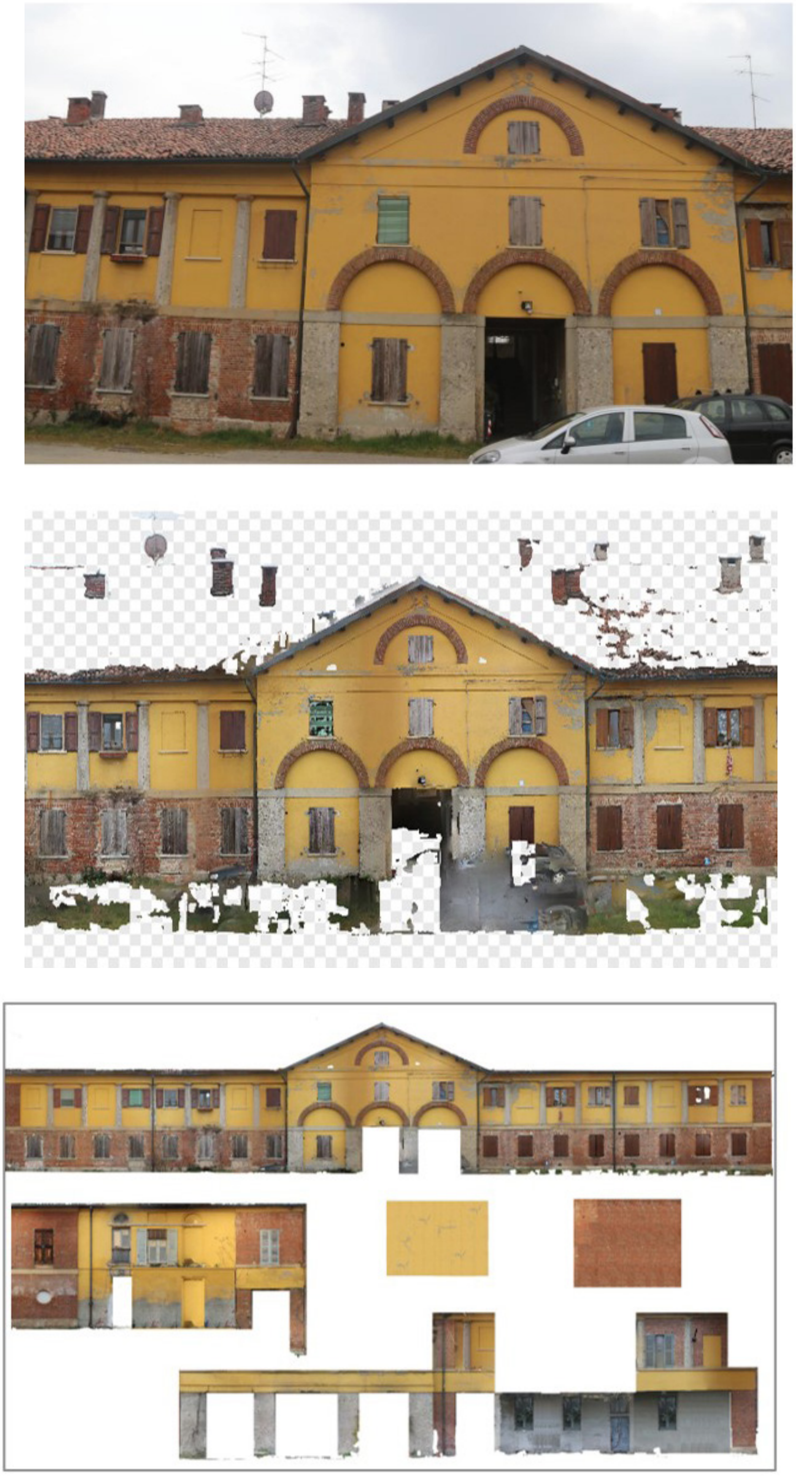


Fig40. The transfermation of 2D heritage information from site photo (top), orthophoto (middle) and texture map (bottom)

as feasible. In practice, we carry cameras throughout the facility in order to capture any surface that may be photographed. At the plane, ensure that each pair of images overlaps by at least 50 percent, and snap a photo at each corner every 10 degrees of camera rotation. To ensure the originality of textures, we document the material information to the fullest extent possible.

First, 862 photographs were captured using Canon cameras and imported them to the computer in jpg format (5.82GB in total file size). Then, all photographs are sorted by building and loaded into metashape to make distinct pieces. Each chunk

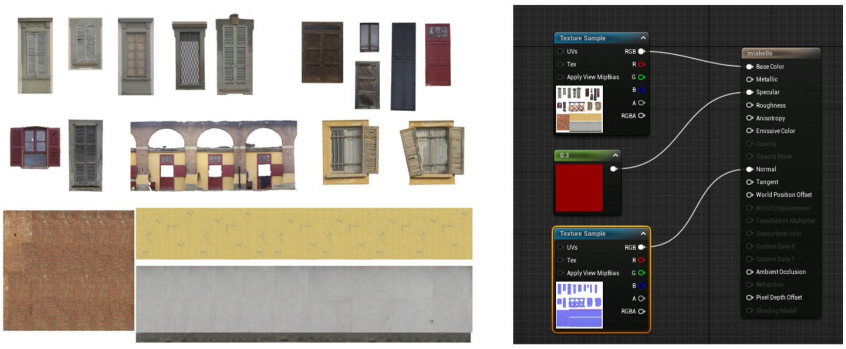
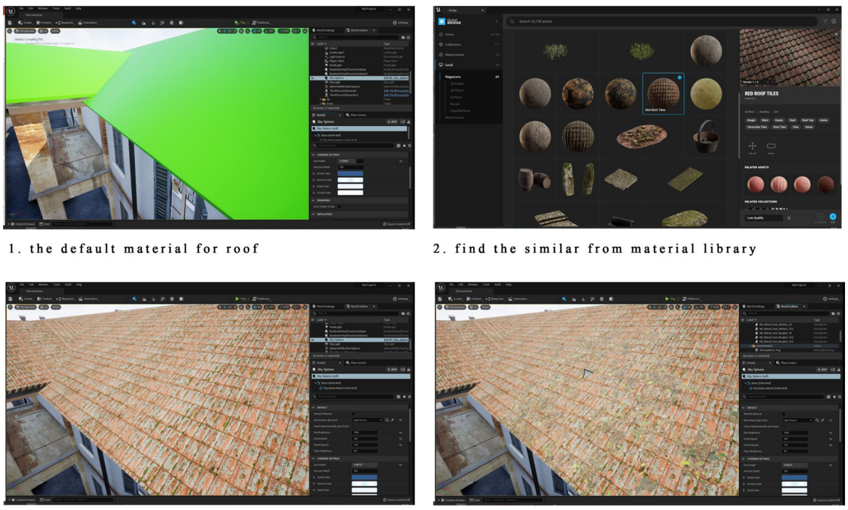


Fig41. The major material and its settings in UE5 shder system (self drawing)


1. the default material for roof

2. find the similar from material library

3. substitude the default

4. add decals to be realistic

Fig42. Use material and decals from online library for typical area (self drawing) represents a building, and metashape's align images function can establish their spatial position and construct a 3D point cloud by identifying the relative relationship between photos. However, owing to the shooting angle, lighting, obstructions, etc., not all imported photographs can be recognized, as only 792 photographs were correctly identified. After producing the point cloud, metashape can produce a surface mesh model based on the point cloud. To assure the accuracy of the particulars, we choose for the maximum level of precision. Through the mesh model, we are able to draw markers in the program window and intersect the needed elevations to obtain high-quality orthophotos. Through this method, the building's material information is efficiently transported and maintained at the highest standard. The Metashape photogrammetry procedure's specific parameters and settings are as follows:

-Add chunks for each building's photographs to be imported.
-Arrange images (Accuracy: High)
-Produce Mesh (Quality: High)
-Generate orthomosaic (Enable Hole Filling).

It is strongly advised to process these data on a computer with a sophisticated graphics card. HP Omen 15, Core i5-10300H, NVIDIA GeForce RTX2060 is the PC configuration for this project (6GB).

The produced orthophoto was subsequently imported into Photoshop for further processing. The purpose of the editing was to address three issues. First, summarize the primary building materials (brick, white plaster, and yellow plaster) and create the texture for wide area assignment. The second step is to isolate the primary construction elements (window frames, sun visors, doors, etc.) to simplify photo modeling. The third step is to eliminate redundant regions: for constructing surfaces with similar materials, we utilize the same texture and delete the redundant parts. This will aid in reducing the size of the map and enhancing the 2D information efficiency of the material. A condensed and streamlined texture base map was completed after the editing process.

Despite the fact that the base map indicated the material's color using the RGB scheme, surface roughness were not taken into account. Thanks to Photoshop's 3D workspace, surface bumps may be automatically identified and calculated based on a color base image. Technically, the map containing bump data was referred to as Normal Map. By combining base maps and their related normal maps, both color information and bump information can be conveyed.

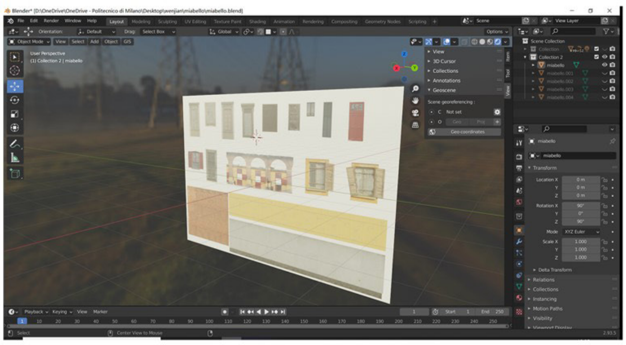
The material map's file size determines the performance quality of a material. Due to the fact that UE5 only permits a single texture map with a maximum size of 16K pixels, the processed maps in Photoshop were saved with a 300 pixel resolution and A1 size. The graphic area was oriented in the image to be as compact as possible in order to more effectively convey the material information. Each material map and its accompanying normal map have a file size of around 20Mb. In the end, ten maps with a total file size of 317MB were produced. The mill required four maps, the Cascina Casalta structures required five, and Mirabello simply required one. Compared to the 5.86GB site image, it is evident that the material information has been compacted incredibly and successfully.

From Texture Maps to Realistic Models

UV mapping these textures on the 3D model is the next stage. The workflow3—Texture in Blender is the most effective method for texturing the project, as explained in the workflow design. Rhinoceros exported the 3D model in obj format to Blender. The model must be converted from NURBs objects to polygon mesh objects before exporting for Blender to recognize it. The layer information and group information are not required for exporting, and the subdivision level should be set to its maximum to ensure that the exported objects are flawless.To texture the model, the objects and texturing are classified in three distinct ways:

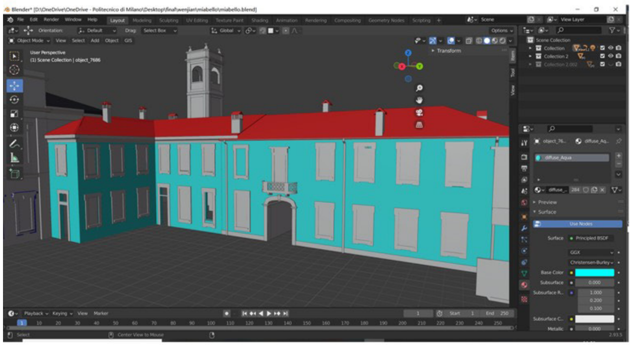
1. textured via orthophoto

For those who can be textured from orthophotos, photogrammetry can document the outside surface. In this material, Photoshop-saved jpeg orthophoto maps are imported into Blender in order to generate materials. First, add a new material to the material characteristics. After that, we can navigate to the "Shading" toolbar, input image texture, and connect its node to the base color to complete the material settings. The produced material is then applied to the objects. At this step, the material is mapped by default, and the object's texture cannot be in the correct position and size, as seen in the picture. Therefore, UV mapping is required. The UV editing bar enables the user to enter the UV mapping system and utilize Blender's powerful UV mapping capabilities. The program gives many options for unwrapping the surface, with "project from view" being the most common option for projecting a 2D orthophoto image. After projecting,

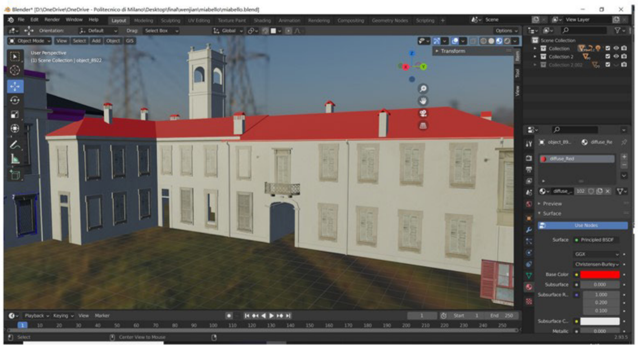


1. create material as plan in blender

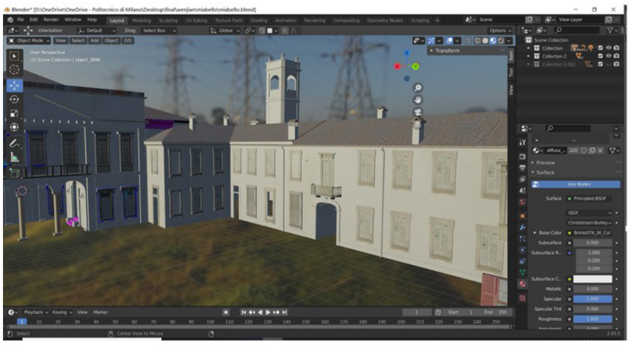
2. extract components in 3D



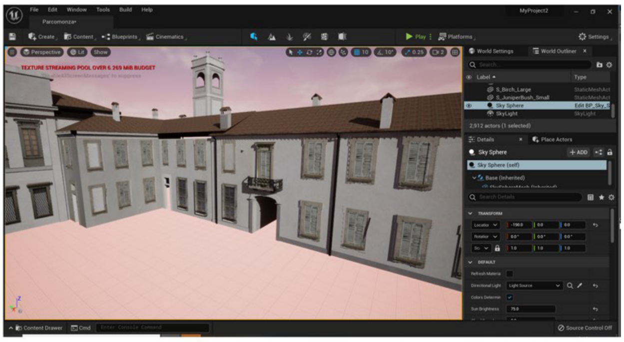
3. UV mapping the model in Blender



4. apply texture and extracted 3D components



5. texture the roof from material library



6. parameter setting in UE5

Fig43. Break down of applying texture map on 3D model approach (self drawing) the unwrapped UV components can be moved and scaled in the UV editing window to match their texture on the input image. By repeating these steps, we can properly position and scale all the texture information from the 2D image onto the 3D objects.

2.textured using the material library

Due to the fact that the part cannot be captured by photogrammetry (interior, rooftops, etc.), we chose a similar material from the material library to maintain as much aesthetic similarity as feasible. In this project, we employed three online-sourced materials: the roof tile texture for roofing, the wood texture for roof support beams, and the steel texture for water pipes concealed beneath eaves.

3.fashioning from the image

For basic architectural components like as windows, doors, and some ornamentation, it is simpler to model on the input image than to texture the image on the original model (imported from Rhinoceros). This is because these components always have multiple faces with intricate geometries. The mapping process can be quite time-consuming. Instead, it is more practical to re-model these geometries based on the input image in order to save time. The accuracy of the remodeled components can be ensured through the use of proper scaling, which references the scanned originals.

The textured model can then be exported as fbx and imported into Unreal Engine5 (UE5). The fbx file can be imported into the UE5 project by dragging it to the content bar. When importing, we enable the "combine meshes" option in the popped-up options bar and leave the others as default. This can prevent UE5 from creating objects for each individual building component in the fbx format model, saving time.

Material parameters system (shading) is one of the most major advantages of UE5, allowing objects to have realistic visual effects. The default material settings cannot achieve a genuine physical effect. Consequently, instead of adjusting default values, adjustments are made to parameters. Roughness and awe-inspiringness are two spectacular aspects for a genuine effect. To match the actual physical appearance of the Italian heritage material, the spectacular value is always reduced to 0.3 while the roughness value is increased to approximately 3 or 4. Decal is an additional tool in UE5 for adding surface elements. The decals can be downloaded from Quxiel, a UE5-specific library application. The decals can enhance the feeling of realism. Similarly to the physical world, leaves may be placed on the roof and fracture patterns can be applied to the walls.

Blender's hand mapping procedure utilizes texture maps to create realistic clothing for the model. And the addition of decals in UE5 made the decoration more consistent with the physical environment. Ultimately, the digitization is accomplished by extending this strategy to all research buildings.

Fig44. Virtual effect of textured 3D model in UE5 (self drawing)

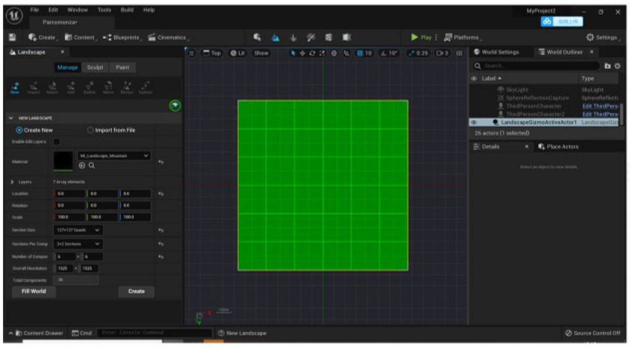
Duplication of the Environment

As the duplication of the heritage buildings is accomplished, how can the environment be duplicated to satisfy the "duplication" objective more completely? How can the 40000 square meter terrain be brought to the UE5 platform with the maximum accuracy? How can the diverse surfaces, heights, and plants be accommodated while maintaining scientific and practical goals?

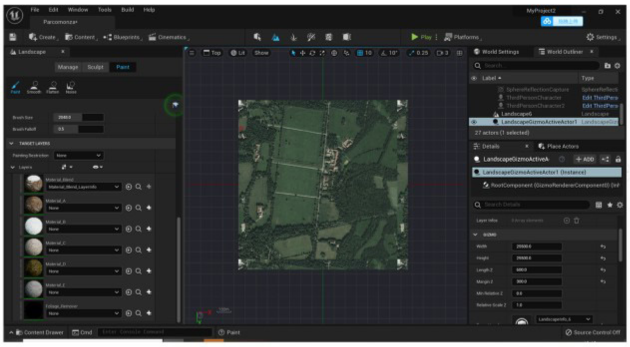
The primary strategy is to collect the site geometry in mesh format using GIS data. Disappointingly, the mesh is not modifiable in UE5, and the effect created by hard edges is phony. With these constraints, it is difficult to achieve the realistic objective. As a result, we utilize the UE5 landscape system as the foundation for the environment. The UE5 landscape system is a sophisticated tool that enables a variety of activities, including geometry scaling, terrain sculpting, texture painting, and programmable vegetation. These characters are capable of accommodating the versatility of geometry editing and realistic texturing. The building of an Unreal Engine environment can be broken down into six steps:

1.Create landscape plane
First, we developed an 800m*800m plane in UE5 to match the project study area. The landscape tool is located in the UE5 window's top bar. This box allows us to select the landscape editing mode and adjust the size of the area we wish to create.

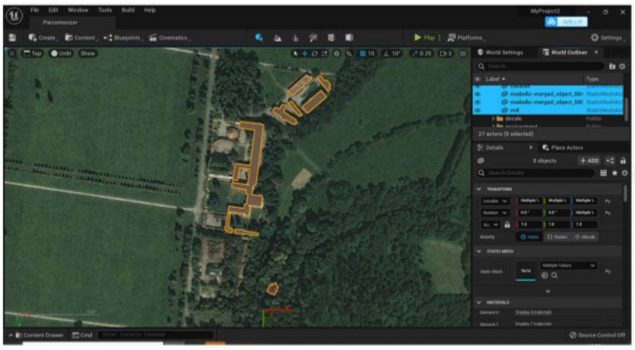
2.Adapt satellite image on plane



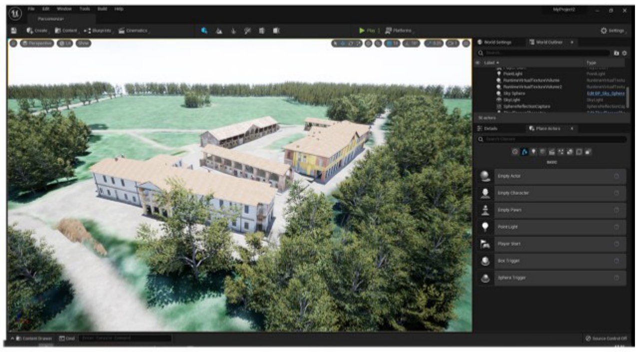
1. create landscape plane



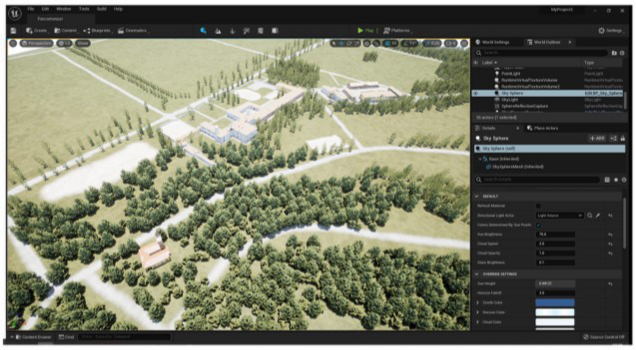
2. adapt satellite image on site



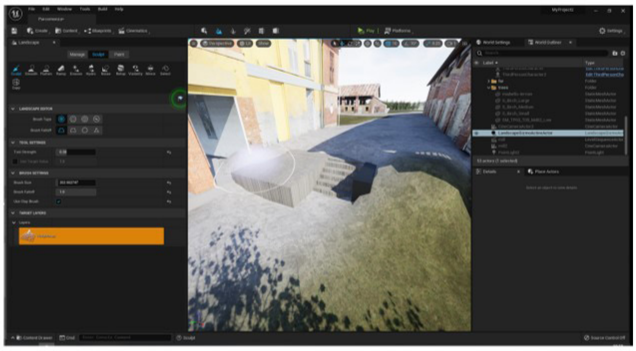
3. locate building models



4. locate trees



5.edit blend material



6. sculpt height difference

Fig45. Approach of environment building (self drawing)

We utilized the satellite image as a basis map to find graphical content on the website. QGIS software was used to generate the site map to provide the best resolution. The image can be made into a material that can be applied to the landscape surface. Thus, topographical details such as roads, buildings, and trees can be distinguished with the appropriate scale.

3.locate architectural models

As the location of the structures has been provided by the satellite image, the generated 3D models of the heritage can then be placed in the correct locations.

4.Plant trees

With the same concept, it is possible to design trees on the surface based on their placement on a satellite map. The trees are then scaled differently to correspond with the real environment.

5.Paint mix material through

Because the satellite map becomes blurry as we approach it, it cannot convey a genuine sense of the environment. The solution is to substitute the satellite image with the specific material. Using the mix material tool, we produce material for roads, grass, and soil, respectively. Thus, the UE5 brush tool can be used to

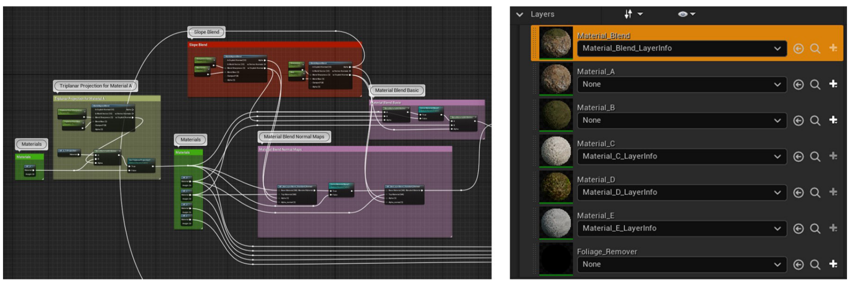


Fig46. Blend material system for lanscape (self drawing)

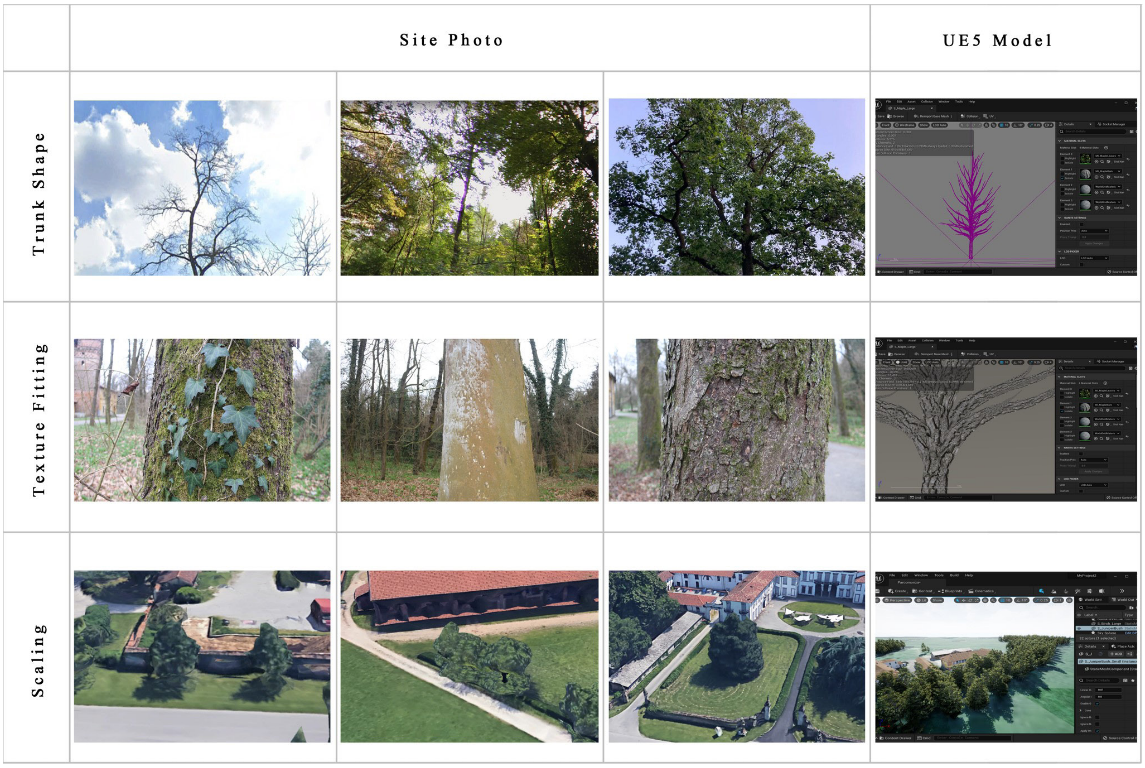


Fig47. Principle of tree recreation from site (self drawing)

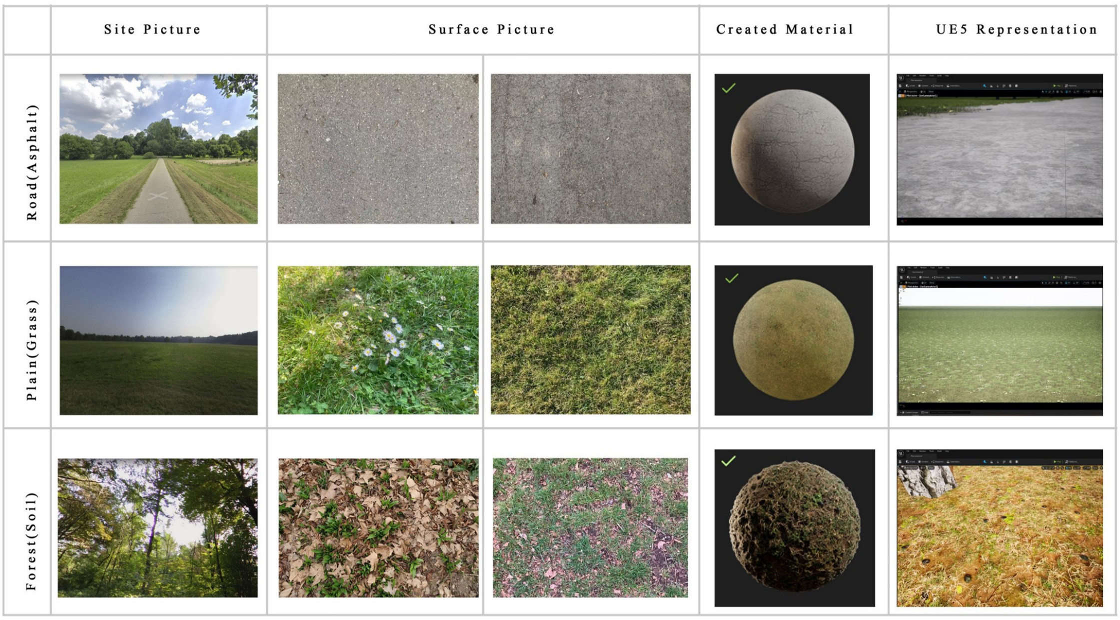


Fig48. Creation of lanscape materials from site pictures (self drawing)

paint through layers to distinguish between grass and road.

6.Reduce height disparity

The terrain cannot be completely flat, although Monza Park is flat in the actual world. Using the UE5 landscape editing tool, we sculpt the landscape (raise and decrease the plane using a circular brush). Due to the fact that GIS cannot be used to man-made landscapes, the height difference information is derived through site visits and Google Earth 3D.

During the building of the environment, extra scientific consideration was given to each stage in order to replicate the atmosphere. The information of assets in the final digital scene is extracted as much as possible from the site. To maintain the project's authenticity, the elements of surfaces and trees are retrieved from photographs taken during the site assessment.

Quxiel Mixer, a professional software for texture editing and processing, was used to generate materials unique to the project for the surfaces. Initially, the site's photographs are imported into Quxiel Mixer as jpg files to serve as a basic color map. Then, the features for a realistic portrayal can be added. Cracks, particles, and bumps can be blended into the surface to make the material appear more realistic. The reproduction process is based on the findings of the site survey, and the final material is exported in jpg format. The material extracted the information using a mixture of various maps, such as the base color map, roughness map, normal map, etc. By dragging the maps to their proper spots, the maps may be imported into UE5 and used to generate materials in its shader system with minimal material. The generated material was then applied to the surface layers of the landscape blend material. In this approach, the final effect can be rendered in a manner that is both scientific and efficient. As the concluding effect offered by UE5, we can detect various fractures in the asphalt, wind-grown flowers on the grass, and falling leaves on the forest floor. This attention to detail can significantly enhance the authenticity.

In terms of environmental geometry, the most important technique consisted of identifying the vegetation using the mobile application PlantNet and replacing it with the same species (maple, birch, and oak) discovered in an online repository. The geometries are gathered from web resources and kept in the project's content after a considerable amount of work has been devoted to seeking, comparing, and collecting. Then, we imported the acquired

Fig49. Virtual effect of project environment in UE5(self drawing)

geometry into the UE5 foliage system (a programmable plant tool) and "brushed" the vegetation on the satellite-generated terrain. In this procedure, the size of the brush could be altered to accommodate both fine and broad distribution. To simulate reality, the plants could be arranged with random orientation and spacing. To maintain the authenticity of the information, we also use Google Earth 3D to organize the size and placement of trees. In addition, the program enabled the plant geometries to adapt to the wind. To enhance the sensation of realism, the leaves can sway in the same environment as natural foliage. Another attempt was made to incorporate contextual components from an online library, such as stones, stairs, and abandoned things of daily life. These things are created by specialists with a high level of detail, making it difficult to distinguish them from the actual world. These improvements are intended to enhance the scene's authenticity and bring it to life. All things are collected with patient reference in a duplication to replicate the site environment in a relatively thorough manner.

In conclusion, landscape data were modified in a recreational manner. Though it may not achieve the highest level of accuracy when compared to GIS data, the objective of reproducing and displaying in a realistic and immersive manner could be met with more efficiency. To enhance the visual experience and originality, the digital scene was artistically processed using the most rigorous scientific technique. Thus, the level of realism and accuracy of information coexisted naturally.

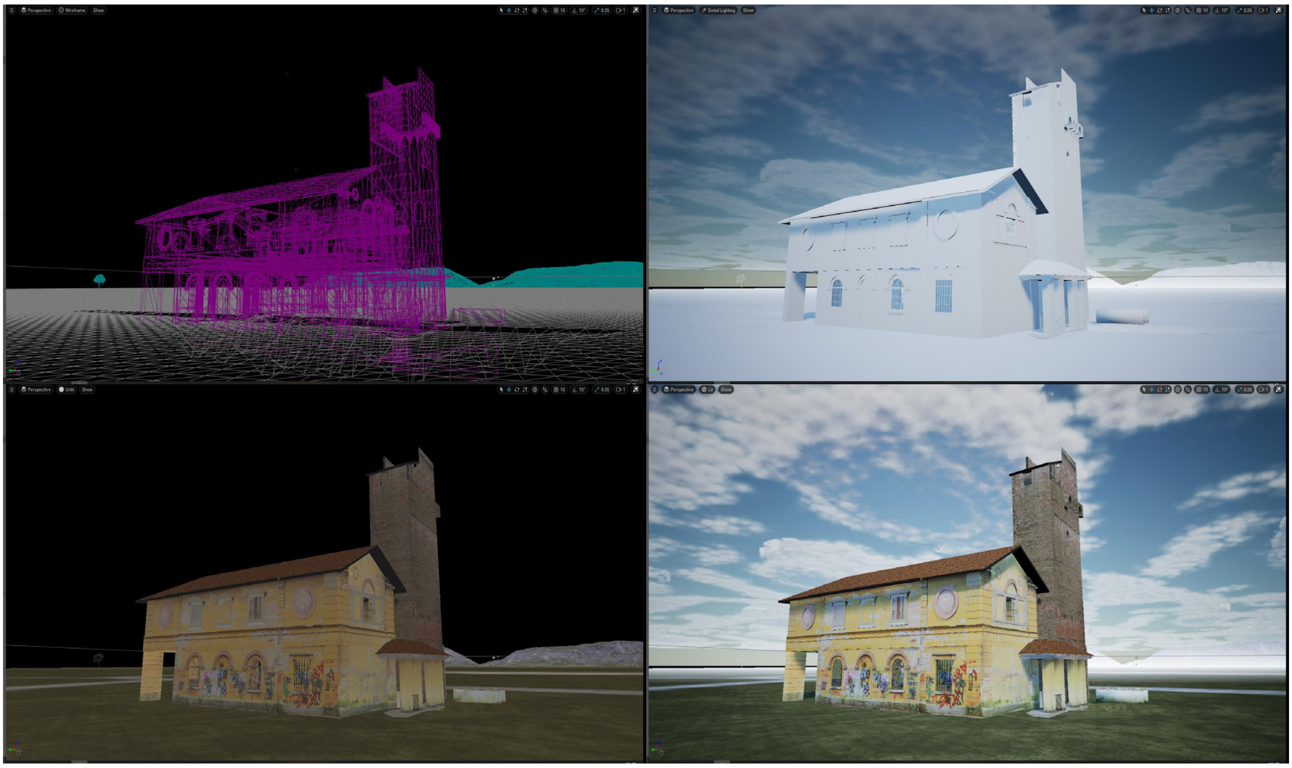


Fig50. Render approach in UE5: Mill (self drawing)

Fig51. Render effect in UE5: Mill(self drawing)

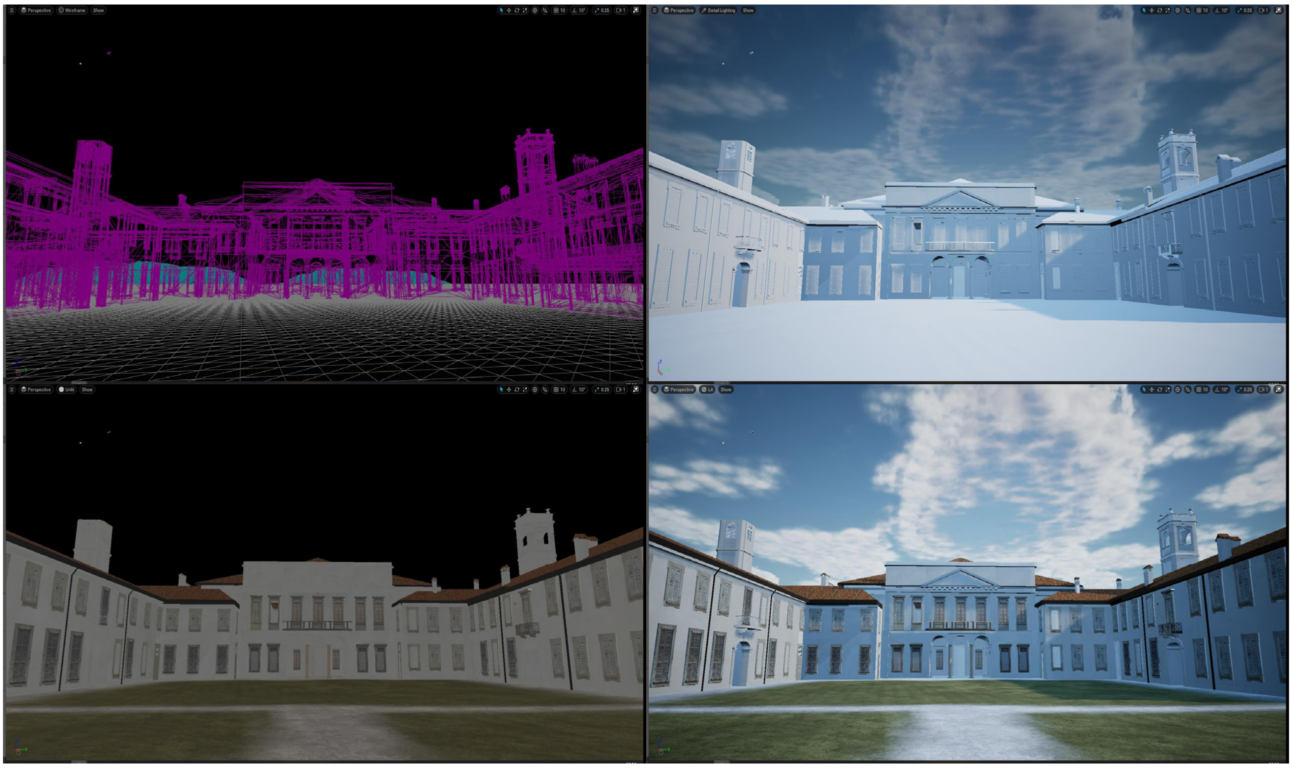


Fig52. Render approach in UE5: Mirabello (self drawing)

Fig53. Render effect in UE5: Mirabello(self drawing)

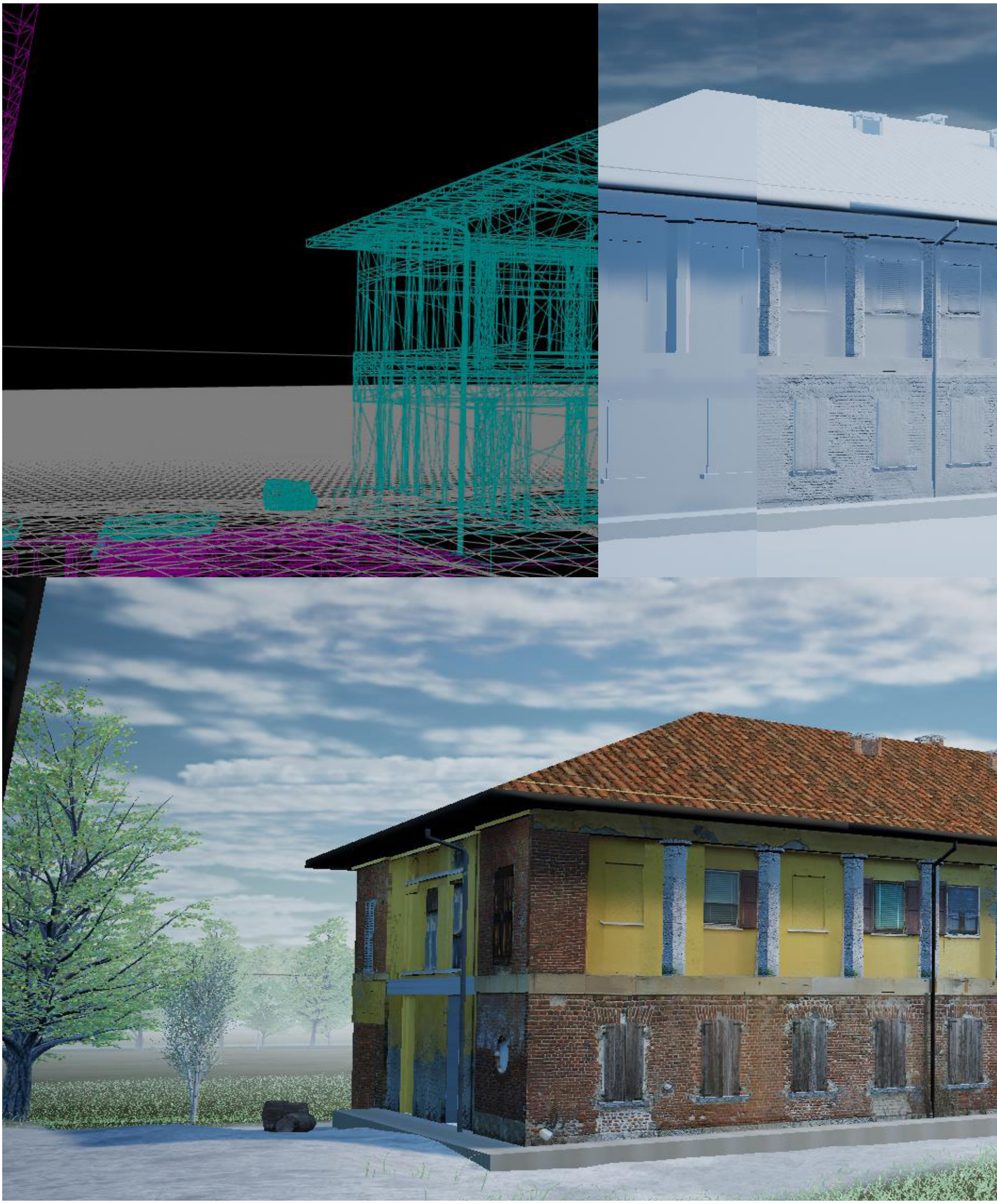
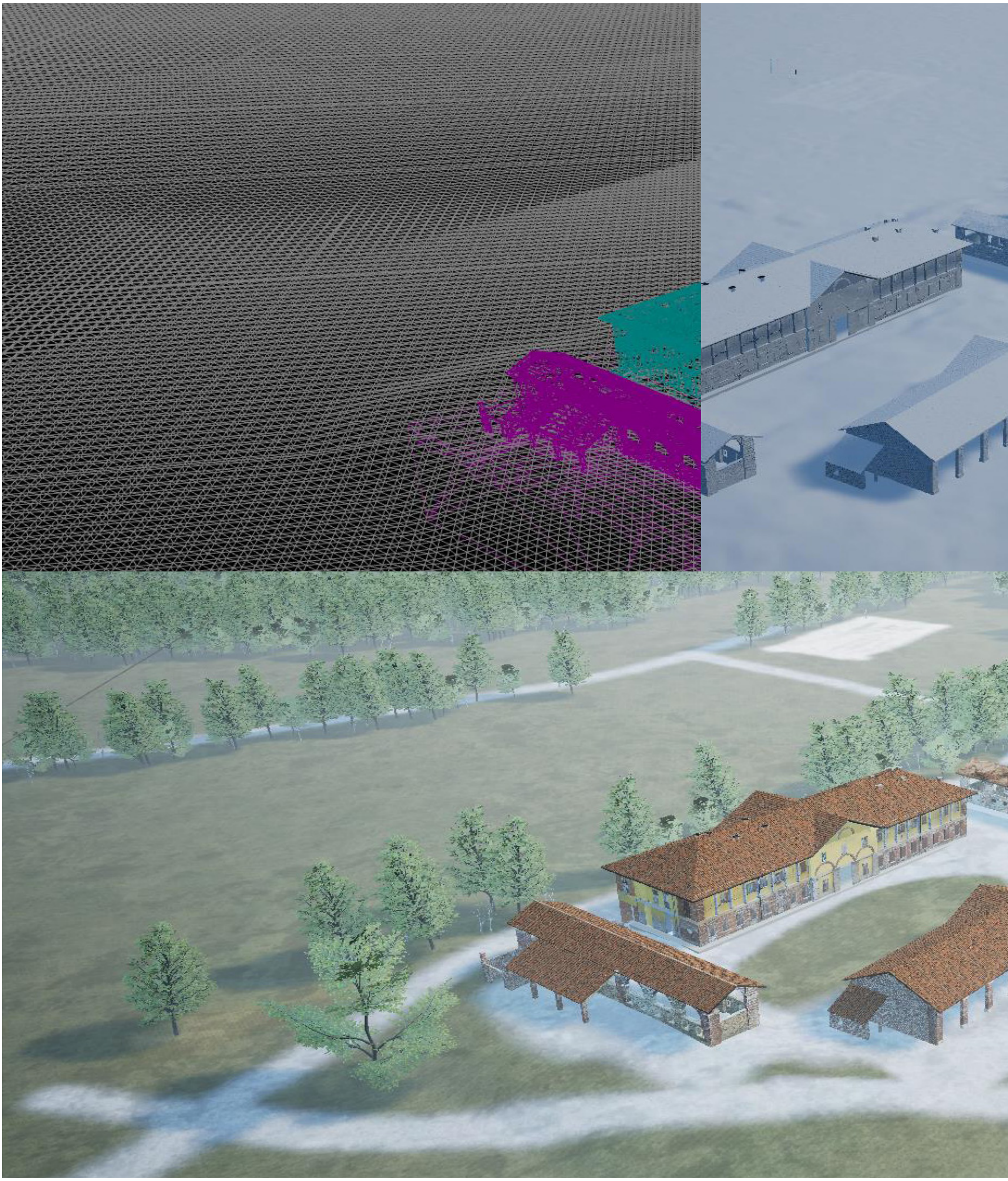


Fig54. Render of Casata in UE5 (self drawing)



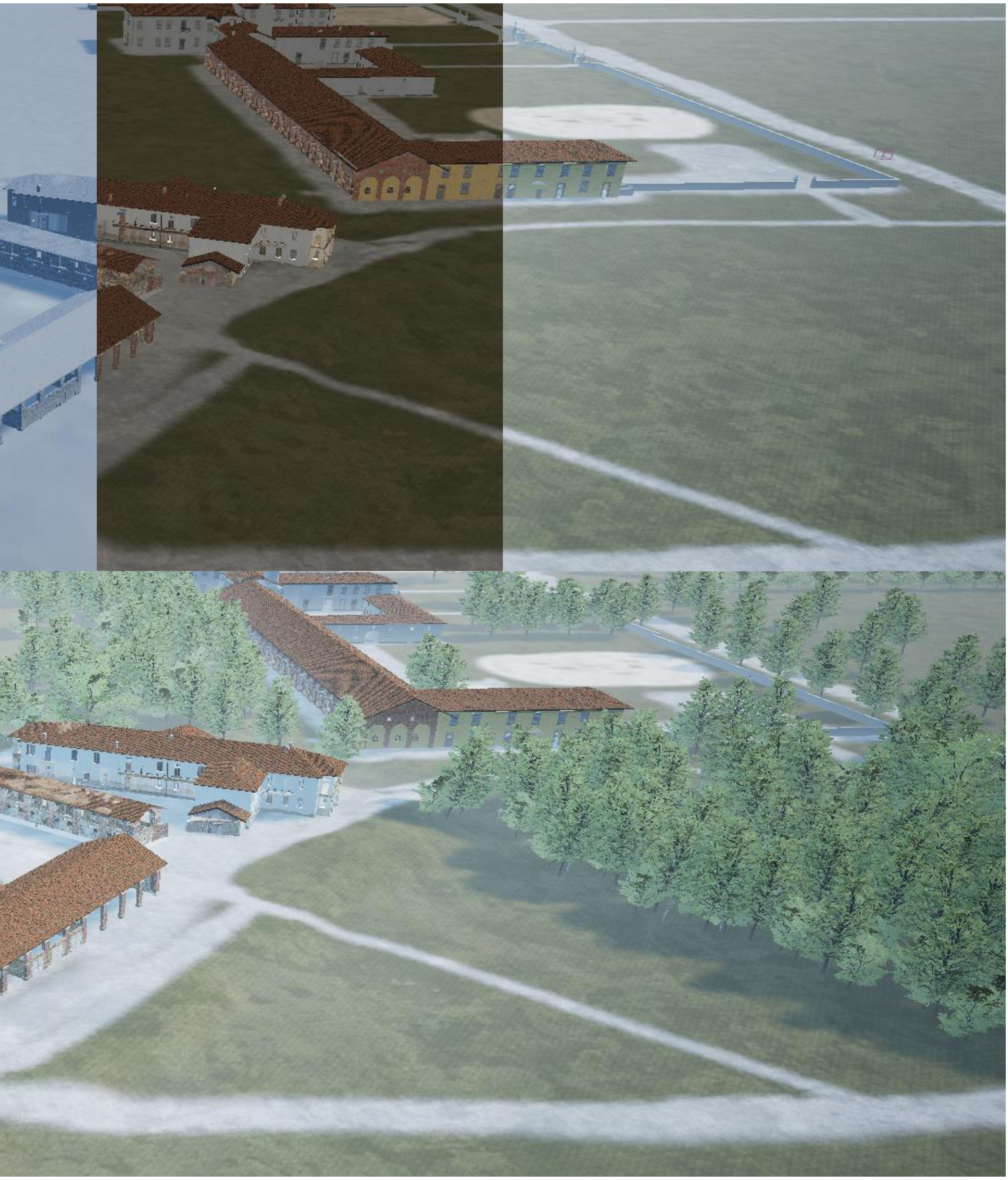


Fig55. Bird view rendering in UE5 (self drawing)

VR Representation

Using VR Oculus, users can have a more immersive experience while walking through the digital scene. Since the content of Monza Park was completed after the environment was constructed, the next step is to engage users with the digital Monza Park. The interaction focuses on enhancing the user's sense of immersion to make him or her feel as though they are in the real world.

One of the most prominent features of UE5's advantages is the simplicity with which users may interact with VR hardware. The researchers injected VR-related functionalities into the project so that users could experience the reproduced scene in a more realistic and immersive manner. This was done so that users could experience the replicated scene. When experiencing Monza Park with a virtual reality (VR) headset, users are able to freely walk around the scene by manipulating the cursor and have the opportunity to see this virtual reality scenario from a 360-degree perspective. Without prior previews expertise, the entire process of configuring and debugging can be completed in just a few hours. The default template for Unreal Engine 5 (UE5) has the parameters for VR interactions. The VR features can then be brought to life by performing the straightforward actions of adding the contents into the project. The template is a collection of programmed programs that can be modified to fulfill the requirements of the job.

The incorporation of a Virtual Reality (VR) function has brought

Fig56. VR charactor walking in the project (self drawing)

Fig57. User waking in the project with VR Oculus (self drawing)

the level of representation of the digital heritage project to a new level. Before, the original visual images of the digital heritage project were only displayed on the computer screen. Now, however, users can immerse themselves in the experience by incorporating multiple senses, including hearing, touch, and space type experience.

Review

Exploration of software operations, error management, and unanticipated experimentation comprised the entire procedure. There could be as many as 20 associated software programs, some of which are not even discussed in this paper because they were rejected at an early stage due to their resemblance in terms of tools but more complexity in terms of use. Throughout the entire process, the filtered software was compared, analyzed, and tested. Error management was always challenging for researchers who were unfamiliar with a given software. It was always difficult to determine the cause of and solution for unknown situations. The author, like the majority of academics in the architecture field, had no prior experience with the majority of the software utilized in this project and had to spend countless hours watching online tutorials and perusing software communities in order to understand its fundamentals and operations. Thanks to the abundance of resources on YouTube and the simplicity provided by Google Search, the author was always able to determine the answer and advance the project. Throughout the course of the task, the author meticulously recorded all pertinent information, including the amount of time and file size. One of the primary objectives of the review is to examine the recorded data for analysis and critique, with the goal of further optimization.

Not all recorded data, however, is counted successfully. The reason for this is that, for example, a wrong attempt always wastes a great deal of time and the software can unexpectedly crash without warning, resulting in lost progress. Second, it is not

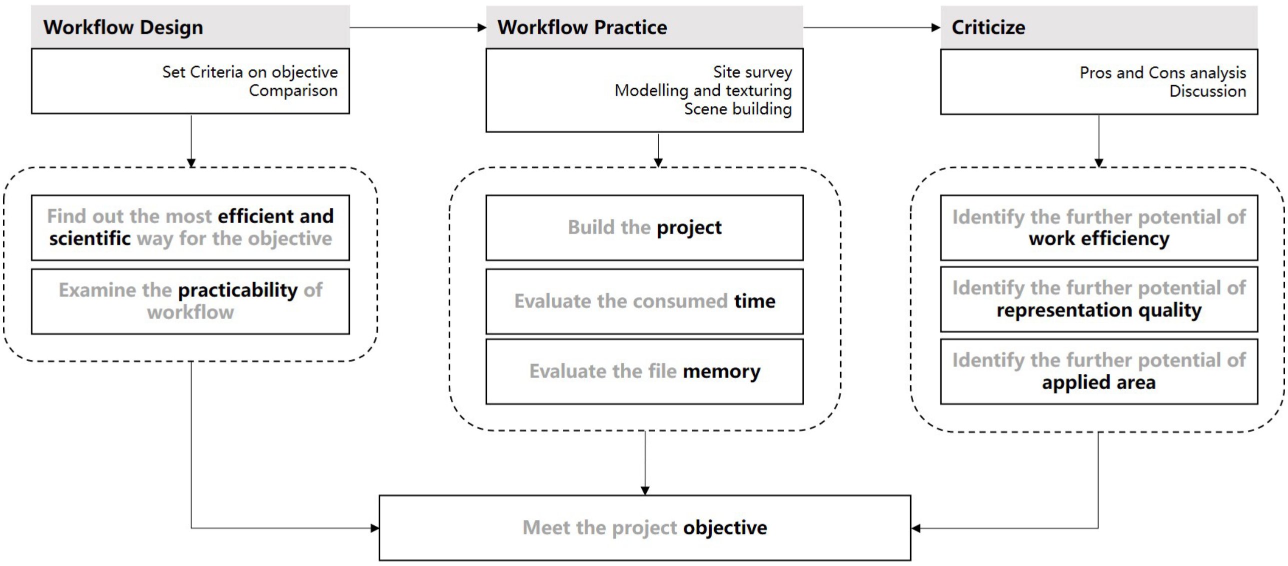


Fig58. Map of practical approach (self drawing)

possible for the researcher to work without a break for the entire duration of the recorded period. To examine the time distribution of the approach, the author evaluated the time cost based on three hypotheses: First, the researcher has complete knowledge of the software's operation, without the need to attend a tutorial and without making any mistakes; Second, the researcher has paid close attention to avoid massive processing, and the software does not freeze or collapse during operation and processing. Thirdly, the researcher must work with undivided attention and without hesitation or pause. As one might expect, though, the time doubles or even triples in practice. Aside from the 3D survey, the entire method takes four months to complete (Cecilia Maria Bolognesi's research team has previously completed the laser scan to NURB model phase).

The figure ends the time cost data with a pie chart to provide a more detailed depiction of the time use. The preceding three hypotheses were used to estimate the data at each stage. The researcher categorized the technique into three distinct sections, namely documentation, representation, and dissemination. In order to introduce the laser scan in greater detail, it encompasses the duration between the 3D survey and the development of an appropriate NURB model in Rhinoceros7. Photographing, computer processing, and Photoshop editing are all components of photogrammetry. In order to precisely combine 2D information with a 3D model, the UV mapping procedure is performed manually. It takes time for the collecting of assets and Geo-reference reproduction to duplicate an environment. Using the existing UE5 template, the incorporation of VR equipment is simple and requires little effort. As indicated by the pie chart, the majority of time in the representation technique is spent on texturing objects. The reason for this is that every surface must

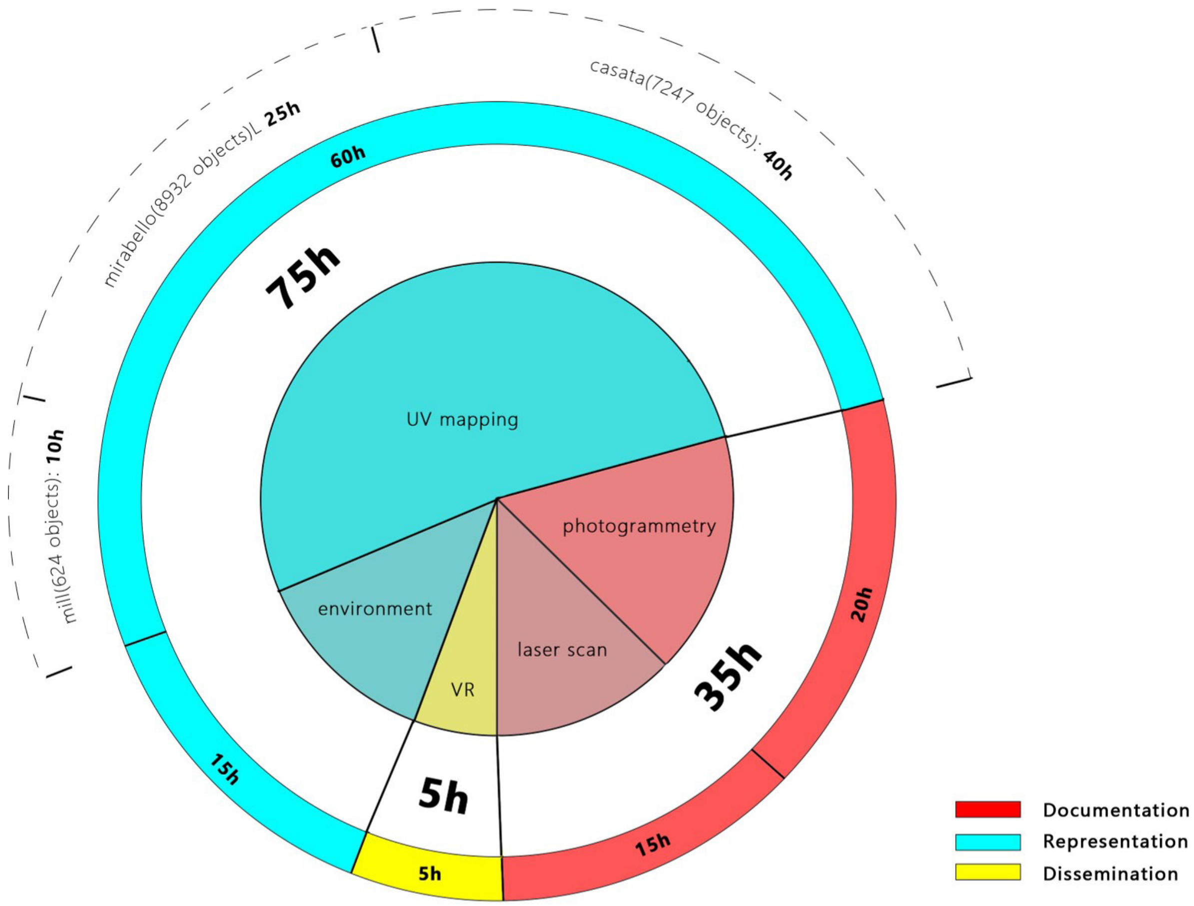


Fig59. The evaluation of time distribution throughout the "duplication" process (self drawing)

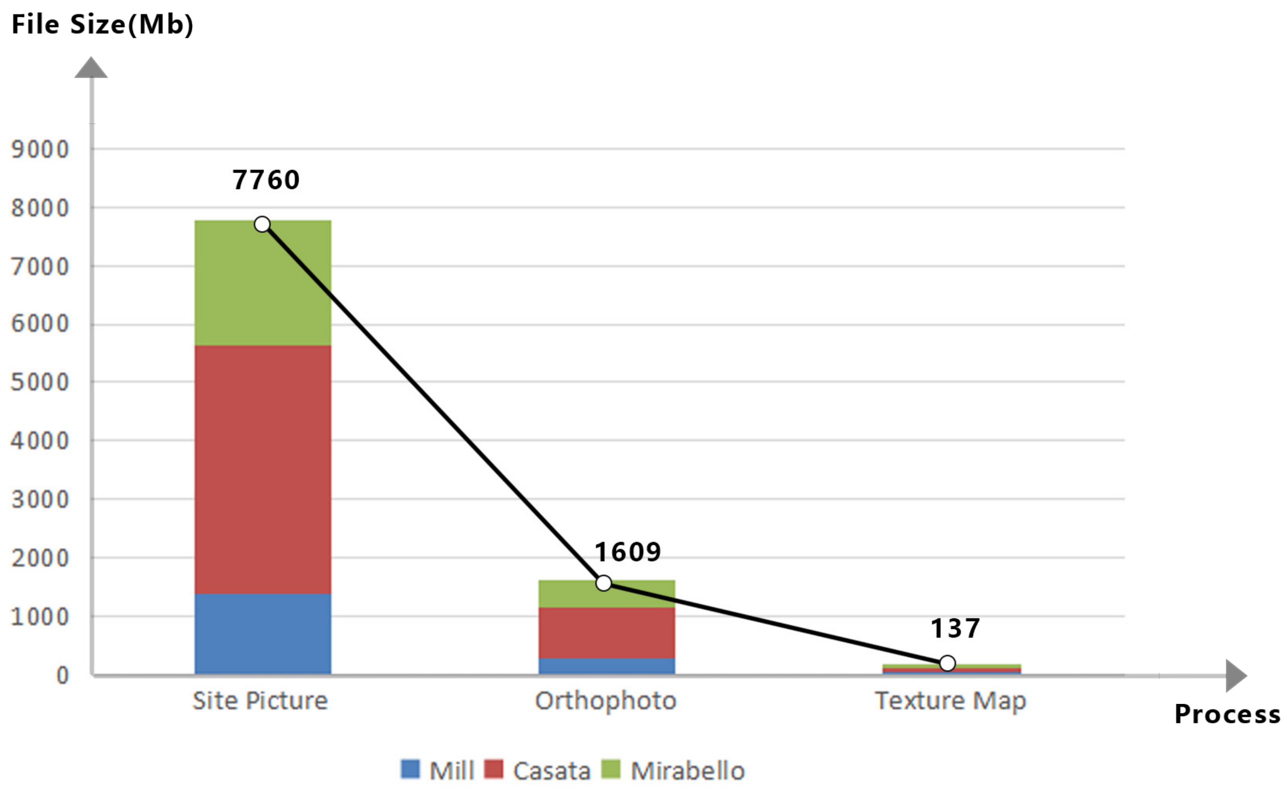


Fig60. Texture file size variation throughout the approach (self drawing)

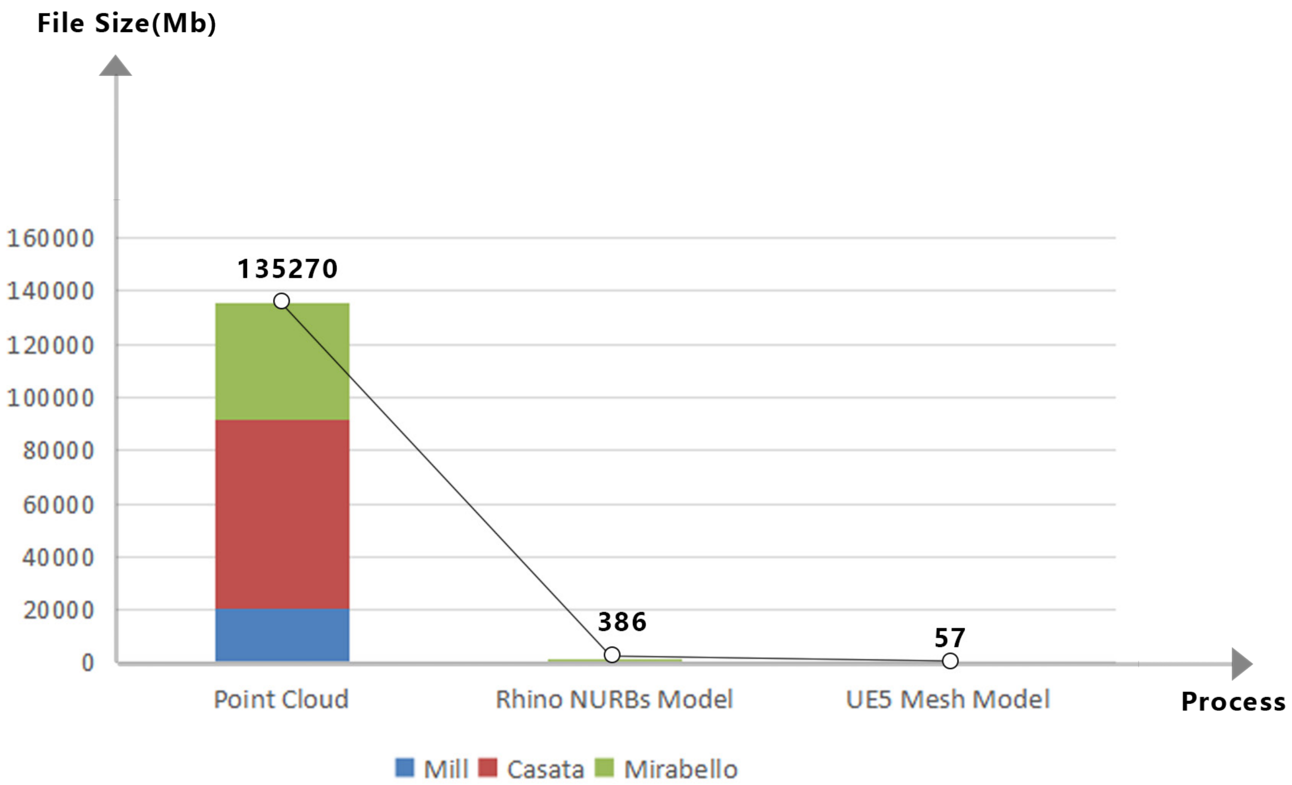


Fig61. 3D model file size variation throughout the approach (self drawing)

be unwrapped and UV mapped manually and precisely. Texturing time depends on the size and complexity of the building, as shown in the table. Texturing the Mill takes the least time due to its tiny size, whereas texturing the structures in Cascina Casalta takes 40 hours due to the high volume of 7247 objects. The reason why Villa Mirabello with more objects(8932) took less time is because the building volumes are connected and we just needed to produce one texture map for the entire layout (compared with 5 maps created for Cascina Casalta). This outcome may contribute to the workflow optimization for expediting. W The documentation phase is equally time-consuming, but we recognize that the manual technique of photographing and configuring laser scanners on-site is necessary and offers little opportunity for time savings. Even though data processing plays a significant role in the documentation process, it is automatic and variable due to the variable performance of the computer. This project does not devote a great deal of time to disseminating its content, as its primary objective is duplication, not growing its reach or incorporating interactive features. The sole purpose of the VR strategy for project dissemination was to establish a connection between users and the project, which is seen as fundamental. Theoretically, with a greater understanding of user interface (UI) design, this digital heritage project's overall quality can be enhanced by incorporating further interaction into the dissemination strategy. However, it is not carried out because it does not contribute to the objective of duplication.

Throughout the project workflow, the researcher calculated the file size of 2D information (textures) and 3D information (models) in terms of file size. In the first step of the material preparation process, the 2D information is changed in three steps: recording the information by taking site images, utilizing photogrammetry to obtain orthophotos, and Photoshop to trim the orthophotos into usable texture maps. The 7760MB of camera-captured site photographs were reduced to 137MB of texture maps throughout this procedure. This indicates that during the collection and distribution of 2D information, the proposed workflow successfully compresses the information to the initial 2 percent, hence optimizing the sharing of 2D information. Through a number of processing steps, 3D information documentation has also been considerably streamlined. Initial laser scan results produced a 3D point cloud that exceeded 130 GB. The precise NURBs model was substantially reduced to 386MB after being processed programmatically in Rhino7. In addition, the NURBs model was manually processed in Blender, and the rebuilding of several over-subdivided objects reduced the model's import size into UE5 to 57MB. The compression efficiency reaches 99.6 percent when compared to the original point cloud.

The authenticity of the virtual digital scenes was evaluated by comparing them to photographs taken in the actual world, both from the perspective of a bird and that of a person. In spite of the color tone, the accuracy of the geometry and the information about the substance have become exceedingly near. The buildings, roads, and vegetation of the entire site in the virtual project are in the same place as they are in the actual one, and the geographic location information obtains an adequate level of accuracy as a result of this procedure. The overall model details and material similarity of the buildings have reached the standard required by the "replication" system. When viewed from the perspective of people, first and foremost from a distance, the relative size and position of the buildings on the site are very consistent with the actual photos. Second, the material characteristics of the building surface have also reached an extraordinarily realistic level when

Fig62. Comparison between real world and virtual digital objects (self drawing)

viewed from a close distance. Both the uneven cement surface and the unevenly colored bricks have been properly conveyed in this representation of the structure.

Weakness

1.The texture was not scaled exactly enough, especially when it came to seamless areas like walls, bricks, and roof tiles. Because the deviation is determined manually, the mapping cannot correspond with the actual size.

2.The surface luminance was not uniform in areas with shadows. Shadows produced variations in the intensity of the acquired texture maps due to the varying light conditions during photogrammetry. Despite the fact that the maps were Photoshop-processed in an effort to prevent the occurrence, there are still unrepairable portions.

Instead of 3D scanning the vegetation, it was rebuilt. In this project, the 3D geometries of trees and grass were obtained from online markets. In terms of reproducing the diversity of the actual natural environment, the samples have their limitations.

Potential

1.The physical labor can be delegated to a larger number of researchers through teamwork, with a greater emphasis on texture scaling on each surface. The texture mapping procedure might be divided if there are multiple participants. With a greater emphasis on scaling and offsetting, additional effort can be devoted to the mapping of every surface. This will without a doubt increase the accuracy and depth of detail of the researched heritage.

Optimizing the surface intensity to be more realistic is possible.

There are two options for resolving the issue of unequal intensity. The first is, at the stage of site surveying, to choose a cloudy day and capture photographs with no shadows or light contrast. The optional step involves adjusting the intensity in Photoshop when modifying texture maps, which would be imprecise and difficult.

3.The simulated environment can be made more realistic. More time might be devoted to the acquisition of trees and plants that are comparable to those already gathered nearby. We do not think tree modeling to be important because there are no trees in the park that are particularly notable. However, with further samples, the resemblance between digital trees and actual trees in a park could become even more striking.

Secondary Development Anticipation in Dissemination

As we have already explored the techniques and reasons for this duplication behavior in terms of documentation and representation, we are also interested in the dissemination of this information. Would the duplication actually be advantageous? How might our efforts assist Monza Park and its surrounding community? How will future generations be truly appreciative of the digital preservation of these cultural artifacts? Despite the fact that the answers are not readily discernible, the author attempted to provide his own predictions for secondary development in order to fulfill the challenge.

Digital media have connected the world in a manner that is becoming increasingly inseparable. Blogs, films, and programs have an ever-increasing influence on how people perceive the world today (Wiederhold, 2020). With the correct design of the digital product and promotion, the Digital Monza Park could become more well-known and of interest to the general public, resulting in economic or social benefits. For example, attracting visitors and administrative attention for increased consumption and investment.

2.An educational experience:
The VR headgear has been used for educational purposes because of its ability of connecting several senses (Freina & Ott, 2015, April). And the case study of Cyark in Capter2 shown that digital heritage has an educational impact. In this scenario, we may construct a multi-level interactive design to strengthen the link between users and the project, thereby enhancing the gaming experience, as well as a multi-page interactive design to expand the content.

3.An application for research:
The digital model can include more architectural information, such as decays, material, and dimensions. However, information should be represented in a representation that is user-friendly. In this instance, secondary development can concentrate on the design of the information and digital model's integration.

Conclusion

The digital duplication of physical cultural heritage could be accomplished even without a great deal of professional experience due to the software's sophisticated capabilities and open-source training. The idea framework of digital heritage approach and interpretation aided the comprehensiveness in this sector from a historical and social perspective, thanks to the scholars and literature evaluations. Due to the contribution of research articles to the most recent workflows, the error rate in this unique project may be kept within the most manageable range. To contribute a brick to this field, the project aimed to be exploitative based on the obtainable knowledge of existing technologies, methodologies, and concepts. The project was completed with the achievement of its objectives and the capacity for ongoing development and exploitation. To summarize the complete strategy, the creation points can be summed up as follows:

1.The author advocated the objective of realistic duplication and immersive representation by combining a digital heritage scenario with an observation of the contemporary era.
2.In terms of methodology, the project utilized the most effective tools in conjunction with the most up-to-date software, along with repeated efforts, trials, and optimizations.
3.In terms of methodology, the article achieved the originality and authenticity of both the environment and the buildings, with a thorough introduction that enables non-specialists to comprehend, refer to, and engage in practice.

4. Regarding further optimization, the data was visually evaluated to assess the approach's deficiencies and opportunities.

5.As part of the project's secondary development, the promoted scenarios take into account social and economic factors.

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