POLITECNICO DI TORINO

Master Degree in Biomedical Engineering

Master Degree Thesis

Making Heritage Accessible: Museums and Heritage Building Information Modelling Applied to Neurodiversity Cases

Supervisors

Prof. Anna OSELLO

Candidate

Cosimo LORUSSO

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Abstract

According to the latest agenda issued by the International Council of Museums (ICOM) – the world's leading organization for museums – cultural venues shall be intended as places where inclusion must hold a hegemonic place of attention throughout the curation, exhibition, and delivery phases. In addition to architectural barriers – formalized since the late 1960s in the Italian law and practices - such venues must indeed consider neurodivergence as a new variable of inclusion and accessibility – aided by the digitization of the cultural heritage, which is yet another priority of this new agenda. Indeed, between 15 and 20% of the world population hold a form of neurodiversity – thus altering the perception and reception of cultural experiences, which are often designed *from* and *to* the perspective of neurotypical individuals.

Drawing from the provisions set by the ICOM, prioritizing both inclusion and digitization, this thesis seeks to provide a project that operates on a dual theoretical and practical level. The former gathers theories of neurodiversity, cognitive models, and digital learning methodologies applied to the cultural heritage. The latter is designed to conceptualize, develop, and deliver an actual apps for one of Turin's most prestigious museums, Palazzo Carignano. Such apps hybridize 3.0 technologies like Augmented and Virtual Realities (AR and VR), as well as Building Information Modelling (BIM). As the apps were developed through a Design Thinking approach – whereby the app and the functionalities it provides can be integrated and amended throughout the process - the application will be delivered as a fully-functional product with a BIM model of the Palazzo and with a provisional version of both the AR and VR views.

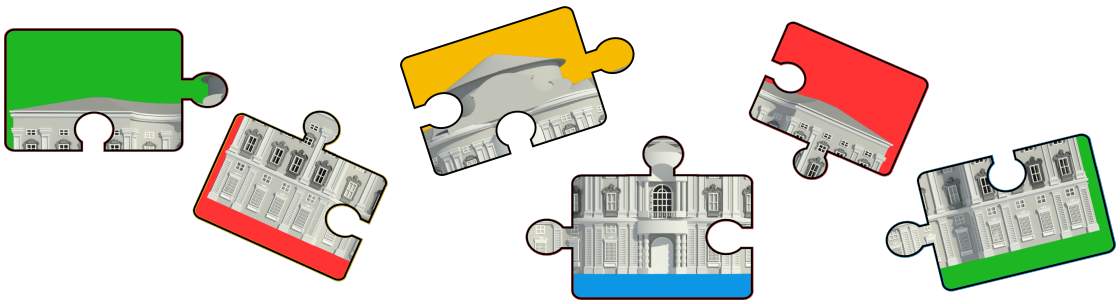
The app was conceptualized and developed on the basis of an hypothetical individual with Autism Spectrum Disorder (ASD) and was revised by a multidisciplinary board of professionals and validating institutions – i.e., the Direzione Regionale dei Musei (the Regional Authority for Museums), a specialized neurologist (Dr. Keller), as well as an association dedicated to autism (Centro Regionale Disturbi Spettro Autistico, ANGSA and Cuori Blu). The successful development of the app will lead to its actual adoption at Palazzo Carignano and also further potential adapation by other venues belonging to the same Regional Museum Authority. Its mobile-based development and functioning indeed democratizes access, cost, maintenance, and accessibilty versus those apps and products created for often inaccessible technologies designed for devices such as VR headsets, 3D holographic display, or *similia.*

Despite the promising future applications, the app may benefit from further biomedical integrations, improvements, and amendments, which may indeed be the very subject(s) of further doctoral studies – which would take place in the world's most prestigious cultural destinations, Italy, which however, at times, fail at providing access to all.

Acknowledgements

I express my heartfelt gratitude to Professor Osello for providing me with the opportunity to delve into the subject of inclusion within museums, which may initially appear distant from my academic background in biomedical engineering. I extend my sincere thanks to all my colleagues at the Drawing to the Future Department for introducing me to the multifaceted world of BIM.
Furthermore, I would like to express my deep appreciation to my family for their unwavering support and patience throughout my university journey, which had its share of challenges but ultimately led to my graduation. To my friends, I want to convey that you are already a part of my family, and I am truly grateful for your presence. I extend a heartfelt thank you to everyone involved in this journey.

"Diversity is being invited to the party;
inclusion is being asked to dance."
Vernā Myers



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Acronyms

AAC

Augmented and Alternative Communication

ADD

Attention Deficit Disorder

ADHD

Attention-Deficit / Hyperactivity Disorder

AEC

Architecture, Engineering, and Construction

AI

Artificial Intelligence

API

Application Programming Interface

AR

Augmented Reality

ASD

Autism Spectrum Disorders

BIM

Building Information Modeling

CAD

Computer Aided Design

CAE

Computer Aided Environment

COLLADA

COLLAborative Design Activity

DAE

Digital Asset Exchange

DSM

Diagnostic and Statistical Manual of Mental Disorders

gLTF

graphics Library Transmission Format

GUID

Globally Unique Identifier

HBIM

Heritage Building Information Modeling

HMD

Head-Mounted Display

HTTP

Hypertext Transfer Protocol

IBM

International Business Machines Corporation

ICD

International Classification of Disease

ICOM

International Council of Museums

ID

Identifier

IDE

Integrated Development Environment

IEQ

Indoor Environmental Quality

IFC

Industry Foundation Classes

IMU

Inertial Measurement Unit

IT

Information Technology

JSON

JavaScript Object Notation

MBIM

Museum Building Information Modeling

NDD

Neurodevelopmental Disorders

OCD

Obsessive Compulsive Disorder

ODD

Oppositional Defiance Disorder

SDGs

Sustainable Development Goals

UML

Unified Modeling Language

UI

User Interface

V0
: Historical Video

V1
: Video Step 1

V2
: Video Step 2

V3
: Video Step 3

V4
: Video Step 4

V5
: Video Step 5

V6
: Video Step 6

V7
: Video Step 7

V8
: Video Step 8

VR
: Virtual Reality

WHO
: World Health Organization

WISS
: Wearable Immersive Social Story

XML
: eXtensible Markup Language

XR
: Extended Realit

Chapter 1

Introduction to Museums, Neurodivergence, and Digital Inclusion Tools

1.1 When Museums Became Aware of Inclusion and Diversity

Since the 1960s, museums have been at the center of a broad spectrum of feminist, racist, classist, and neurotypical critiques that regarded museums as spaces of privilege for only few – namely white, high-class, heterosexual, and well-educated subjects [1, 2, 3, 4, 5, 6]. Indeed, the great hordes of contestants that originated in this very era (1968 onwards) noticed that issues of representation, accessibility, and inclusion were violated within the very walls of this Institution – that was instead founded to ennoble and dignify the peoples of the newly born democracies worldwide [1, 2, 3, 4, 5, 6]. The waves of contestation were so reverberant that this moment started what is internationally known as the "Museum critique" and therefore the corpus of studies that critically dissects, comments, and eventually perfects what international museum purchase, curate, exhibit, and preserve within the national identity of a given country, repertoire, and memory.

Among the first and most iconic acts of contestation that exacerbated the zeitgeist of this moment was the performance by Christo and Jeanne-Claude *Wrapped Kunsthalle* (1968) in Bern, Switzerland, which provided the complete isolation of the Swiss museum via a great operation of wrapping that surrounded the whole building [7]. By insulating the institution, the international audience could physically visualize the status of isolation – and therefore privilege – museums were benefiting from, and which was the very subject of international critiques.

Through this operation, the wider public could see the net division between the *idealization* shown inside the museum and the *realism* of the outside – the one that indeed characterized their lives. It was however also the museum that, from the inside, could realize its status of isolation, self-ness, and privilege, eventually shaking a deep sense of awareness and a calling to renovate its spirit and mission [1, 2, 3, 4, 5, 6, 7].

Figure 1.1: Christo and Jeanne-Claude, Wrapped Kunsthalle, 1968, Bern, Switzerland [8].

The experience in Bern indeed triggered a global awareness in the realms of museum studies, curation, and art history to the extent that museum directors, art critics, as well as intellectuals, and thinkers worldwide gathered and produced a generous corpus of studies that condensed in annual bulletins, reviews, and reports [9]. The epitome of this generalized movement culminated with the institution of the International Council of Museums (ICOM) in 1946 that not only responded to the global need of harmonizing museum practices, but also the politics, rights, violations, and injustices that its collections, masterpieces, and curatorial approaches perpetuated [10, 11]. The foundation year is indeed iconic; 1946 was indeed the turning point of World War II, its very end, and epilogue. Upon its conclusion, 650.000+ artworks from the European (and not only) scenario were either stolen, looted, destroyed, or lost by the Nazis, impacting on national identities, personal fortunes, and global shame [12]. It was indeed this very spirit that drove countries worldwide to meet and systematize the importance of art and culture, as well as its significance, exhibition and understanding - it was in this historical humus, therefore, that the ICOM came into being.

Figure 1.2: First Global Presentation of the ICOM, 1946, Paris [10].

When the global equilibrium was somehow re-established throughout the 1940s and 1950s, the mushroomed new system of museums had to then tackle with the aforementioned waves of the 1960s and 1970s [1, 2, 3, 4, 5, 6, 7]. It was in this scenario that the ICOM played its first and foundational tasks. It indeed summited in sensitive capitals such as Moscow (1977) and Buenos Aires (1986), spreading a common idea of peace, attention, and awareness that gradually made of it a para-diplomatic and geopolitical institution that sought to provide a global re-management of the cultural heritage through museums [13, 14].

Figure 1.3: ICOM Summit in Moscow-Leningrad, Russia, 1977 [10].

Figure 1.4: ICOM Summit in Buenos Aires, Argentina, 1986 [10].

However, while in the 1950s its priorities gravitated around the aftermath of World War II, the 1960s, as introduced, demanded new policies of inclusion, representation, diversity, and equal rights – thus adding a layer of socio-cultural sensitivity to its functioning and orientation. Since then, the ICOM has indeed activated a meaningful and impactful series of actions, provisions, and global callings that holistically aimed at improving global museum experiences for everyone. Its latest, revised, and updated self-definition indeed reads:

Official Definition of "Museum"
from the Official Website of the ICOM

"A museum is a not-for-profit, permanent institution in the service of society that researches, collects, conserves, interprets and exhibits tangible and intangible heritage. Open to the public, accessible and inclusive, museums foster diversity and sustainability. They operate and communicate ethically, professionally and with the participation of communities, offering varied experiences for education, enjoyment, reflection and knowledge sharing." [15]

The ICOM shall therefore be intended as the very reference to understand museums – their identity, goals, orientations, and evolutions.

1.2 How Biomedical Engineering Meets Museums

While the ICOM has been gaining a global central position in the coordination of museums, also science, and specifically biomedical engineering, has recently joined the mission and provided multifaceted solutions and practices. On a broader level, hard sciences – such as neurocognitive studies, mobility disciplines, as well as psychiatry, physics, and psychology – gathered to approach, study, and perfect the reception of museum experiences from the perspective of non-neurotypical subjects. Among the most successful examples there is "The Neurodiverse Museum"[16], a straightforward project that holds a meaningful objective and name. Its description reads verbatim:

From "The Neurodiverse Museum" Official Website

"The Neurodiverse Museum has been set up to change the way museums and the cultural sector as a whole, approaches neurodiversity. In case you're not familiar, neurodivergence includes autism, ADHD, ADD, dyslexia, OCD, ODD, dyspraxia, dyscalculia, dysgraphia and others.
We aim to shift the dialogue and provision from deficit, person first, exclusionary models, to presumed competence, identify first, inclusionary models with ActuallyAustitic and neurodivergent voice at its heart.
We are currently in the process of developing the next stage of the project and accessing funding to support a wide scale programme to support neurodivergent people to access museums, see themselves reflected through museum display and collecting, and support pathways to the workforce which are currently not available - with lived experience always at the centre." [16]

The name of this museum holds the very essence of this research and therefore the hybridization between biomedical knowledge and museum needs. This museum was however founded only in 2022 and therefore a year ago, and in the United Kingdom only [16]. While research and applications in this field have been mushrooming, most museum environments perpetuate serious accessibility biases and issues that prevent a large part of the population from accessing them [17, 18]. This thesis therefore seeks to participate in this pioneering wave, by applying – on a dual technical and practical level - accessibility tools to make museum experiences accessible, open, and literally demo-cratic – the people, the demos, indeed re-gain

their power and right, the cratos. This pursuit of accessibility is not only supported by international organizations such as the ICOM, but also by the very context in which this thesis is being developed and finalized: Italy. As the world's first cultural heritage country (by the number of UNESCO sites), Italy holds indeed a primary role and responsibility in making its legacy accessible to all, especially to the growingly diagnosed population of neurodivergent subjects, who, in 2022, is estimated to reach 15 to 20% of the population and therefore more than 9-12 million individuals [19, 20]. Moreover, Italy's prestige in the cultural sphere does create an aura of further responsibility on a global scale; the world of biomedical engineering along with hard sciences and humanities shall therefore collaborate to celebrate such a responsibility and deliver world's preeminent technologies and findings. This is indeed the very pursuit of this research and work, which will contextualize up-to-date research along with a practice-based project for one of Turin's most prestigious museums, Palazzo Carignano. For it, I conceptualized, developed, and finalized a fully-functional app, which incorporates all the functions and provisions a neurodivergence sensitive product shall hold. Its design, functioning, experience, and management will be discussed and illustrated in two final appendixes, which practically show the whole exacerbation of the theories cited in the first part of this thesis – thus providing a rounded theoretical and practical experience to the whole field of research.

1.3 Clarifying the Semiotics of this Study: Definitions, Subjects, and Players

This section is dedicated to clarifying the terms, definitions, and implications that will be employed throughout the thesis according the most up-to-date, deontological, and revised version from some of the world's prestigeous sources.
***

1.3.1 Museum and Visitors

As is evident from the aforementioned definition, the museum as a service must prioritize its visitors. Therefore, it is of paramount importance to conduct an analysis on this aspect, taking into consideration the recent definition provided by ICOM. Museum visitors can be anyone such as children, families, academics, residents, visitors and individuals from all backgrounds. Falk [21], a museum scholar, established five identity-related visitor motivation[1] categories that represent the needs and interests people exhibit during a specific visit. These categories are as follows:

1. **Experience seekers** go to the museum because they see it as an important place to visit, and their satisfaction comes from the mere act of having been there.

2. **Explorers** have a general interest in the museum's exhibits and are driven by curiosity.

3. **Facilitators** don't go to the museum to fulfill their own motivation but to satisfy the require of their group.

[1]Falk [22] defines two type of identities:

1. "I" refers to enduring and deep-seated aspects of a person's self-identity that are fundamental to their sense of self and persist over time. This identity is often rooted in factors such as gender, nationality, political views, religion, ethnicity and other fundamental aspects of one's personal identity.

2. "i" is transient and situational aspects of a person's identity that are context-dependent and responsive to specific moments and circumstances. This identity emerges and adapts in response to the immediate social, cultural, and environmental factors at play. Identity-related visitor motivation falls under this category of identity.

4. **Professional/hobbyists** feel a near tie between the museum content and their professional or specialist interests.

5. **Rechargers** visit the museum primarily to have a reflective, spiritual, or restorative experience, using it as a sanctuary from the busy everyday life.

The motivations to go to the museum for each person may be more than one at a given time and they may evolve over time [23]. Therefore, according to the proposed classification, a visitor should not be seen as belonging to a single category and the museum should try to meet the needs of all. Visiting a museum can be regarded as a complex process as it combines different components that are known to interact with health [24].

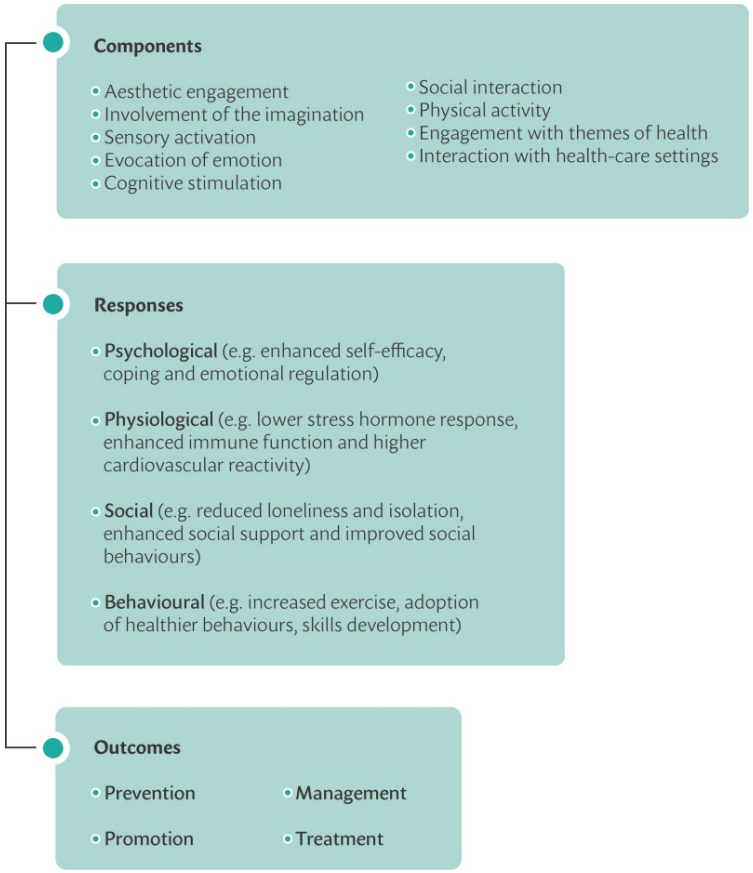


Figure 1.5: A logic model linking the arts with health [25].

The World Health Organization's (WHO) [26] definition of health goes beyond the mere absence of disease or infirmity, instead emphasizing the concept of complete physical, mental, and social well-being. The definition highlights the importance of individual and social well-being, including factors such as social integration, contribution to society, acceptance and belief in society's potential [24]. In the last few years, the museum-health link is becoming a topic of interest both in research and in national and international policies. In order to better understand this connection, two questions will be addressed.

1st question

What is the impact of museums on visitor's health?

There is growing evidence that visiting museums can have a positive impact on the health and well-being of visitors [27, 28, 29]. According to research [30, 31], visit a museum can lower stress levels, make people feel happier, and give people chances to interact with others. However, it is important to note that not all museums are created equal in terms of their impact on health and well-being. Factors such as the type of museum, the quality of exhibits, and the visitor experience can all influence the benefits that visitors derive from their visit.

2nd question

Should the visitor's health be taken into account by the museum?

"NO ONE LEFT BEHIND". The recognition of cultural access as a significant factor in shaping subjective well-being may facilitate the development of innovative and ambitious public health initiatives [32].

1.3.2 Sustainable Development Goals (2030 Agenda)

In September 2015, the 193 Members of the United Nations approved the 2030 Agenda for Sustainable Development entitled *Transforming Our World* [33]. The 2030 Agenda through its 17 Sustainable Development Goals (SDGs) aims to address major social, environmental and economic challenges by 2030. The 17 SDGs and their 169 associated targets serve as a guide for all nations and sectors as they join forces to build a future that upholds human rights and ensures that everyone can live in dignity and security within a healthy, safe environment. The 2030 Agenda may greatly benefit from museums, and certain SDGs cannot be accomplished without them. Mcghie [34], through a framework of seven key activities indicates how museums could seek to align with the 2030 Agenda. Below are the activities:

1. Protect and safeguard the world's cultural and natural heritage, both within museums and more broadly.
2. Support and provide learning opportunities in support of the SDGs.
3. Enable cultural participation for all.
4. Support sustainable tourism.
5. Enable research in support of the SDGs.
6. Direct internal leadership, management and operations in support of the SDGs.
7. Direct external leadership, collaboration and partnerships towards the SDGs.

If this framework were fully complied with there would be an alignment to about one-third of all SDGs, but for the purpose of the thesis there will be a greater focus on activities 3, 6 and implicitly 1.

Figure 1.6: The museum must takes care of the visitor.

1.3.3 Autism Spectrum Disorders

Definition Autism

"Autism spectrum disorder (ASD) is characterised by persistent deficits in the ability to initiate and to sustain reciprocal social interaction and social communication, and by a range of restricted, repetitive, and inflexible patterns of behaviour, interests or activities that are clearly atypical or excessive for the individual's age and sociocultural context. The onset of the disorder occurs during the developmental period, typically in early childhood, but symptoms may not become fully manifest until later, when social demands exceed limited capacities. Deficits are sufficiently severe to cause impairment in personal, family, social, educational, occupational or other important areas of functioning and are usually a pervasive feature of the individual's functioning observable in all settings, although they may vary according to social, educational, or other context. Individuals along the spectrum exhibit a full range of intellectual functioning and language abilities." [35]

Figure 1.7: ARASAAC pictogram: autism

The aforementioned definition is taken from the International Classification of Diseases (ICD-11) which aligns with Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR). This is to say that ASD includes Childhood Disintegrative Disorder, Asperger's Syndrome and certain other generalised developmental disorders [36].

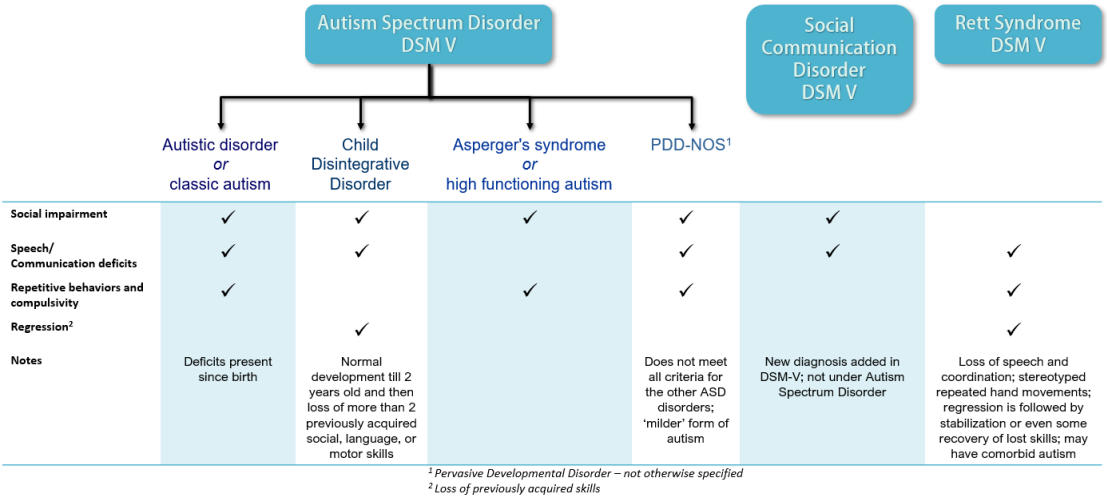


Figure 1.8: Separate diagnosis in DSM-IV that are now under the umbrella of autism spectrum disorder in DSM-V [37].

ASD is a biologically based neurodevelopmental disorder characterized by persistent deficits in social communication and social interaction and restricted, repetitive patterns of behavior, interests, and activities [36]. The sphere of social communication and interaction is assessed through:

- Social-emotional reciprocity;
- Nonverbal communicative behaviors;
- Developing, maintaining, and understanding relationships.

While the restricted repetitive patterns of behavior is evaluate with the following:

- Stereotyped or repetitive movements, use of speech , or objects;
- Insistence on sameness, unwavering adherence to routines, or ritualized patterns of verbal or nonverbal behavior;
- Highly restricted, fixated interests that are abnormal in strength or focus;
- Increased or decreased response to sensory input or unusual interest in sensory aspects of the environment [36].

After assessing these aspects, a patient with ASD may fall into one of the following severity levels:

1. **Requiring support**,

2. **Requiring substantial support**

3. **Requiring very substantial support**

Individuals diagnosed with autism spectrum disorder (ASD) often experience enjoyment and engagement when engaging with computers. This is because computer interactions take place within a secure and dependable environment [38]. As suggested by ICD good practice for rehabilitation interventions, increasing social skills in people with ASD requires a customised approach that takes into account the individual's unique strengths, challenges and interests. Here are some strategies that may be helpful:

- **Social skills training** involves teaching individuals with ASD appropriate social skills through structured instruction, modeling, and practice in real-life situations. This may include teaching skills such as making eye contact, taking turns in conversations, and interpreting social cues [39].
- **Peer-mediated interventions** involve training typically developing peers to interact with individuals with ASD in inclusive environments. This can help individuals with ASD develop social skills by providing them with opportunities to interact with peers in a supportive and naturalistic setting [40].
- **Social narratives** are stories that describe social situations and appropriate behaviors. They can help individuals with ASD understand social situations, learn appropriate responses, and anticipate potential challenges [41].
- **Video modeling** involves watching videos of individuals engaging in appropriate social behaviors, which can help individuals with ASD learn and practice social skills [42]. According to Alpaydin [43], Talal [44], and Plavnick et al. [45], video modeling is especially useful for teaching novel social behavior. Video modeling can be applied officially through a planned curriculum or ad hoc by a provider to a particular student. Video modeling is an easy intervention option for schools because it needs little adult guidance or support [46]. Peer mediation and modeling are subtly incorporated into video modeling. Children watch videos of expected and/or desirable behavioral settings, then practice the behavior on their own. This is how social skills training is given in a way that is comfortable and appealing to kids.
- **Visual supports**, such as picture schedules, social scripts, and visual prompts, can help individuals with ASD understand social expectations and navigate social situations [47].

It's important to note that social skill development is a gradual process, and progress may vary from person to person [48]. A collaborative approach involving

family members, educators, and therapists can help support individuals with ASD in developing their social skills.

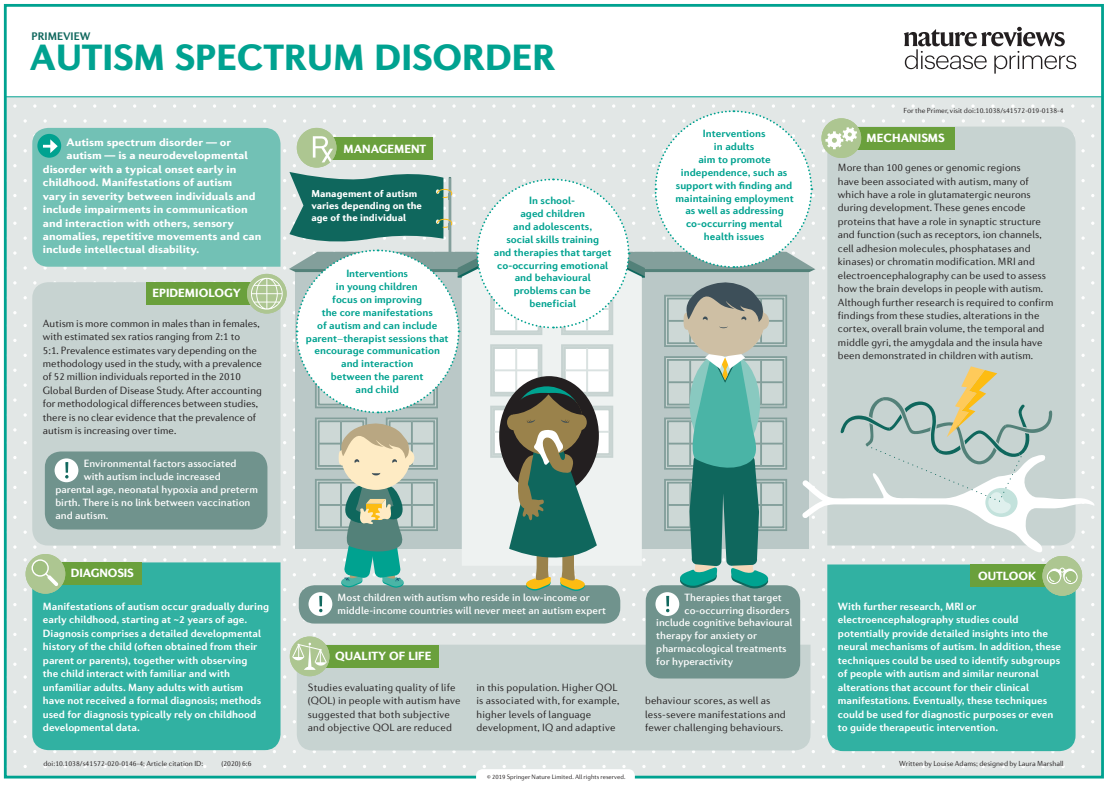


Figure 1.9: This PrimeView provides a concise overview of the management strategies for autism spectrum disorder, a neurodevelopmental condition that commonly presents during childhood [49].

1.3.4 Brief History and Deontological Acknowledgment of the Term "Neurodiverse"

In the previous chapters, there was the harmonized application of the term "neurodivergent" to indicate the final users and targeted subjects of this project. The term, which is commonly employed in the scientific historiography, originates in a non-medical context and, specifically, in the field of sociology. It was indeed Australian sociologist Judy Singer who, back in the 1960s, coined the term to describe the status of autistic person she primarily suffered from, and which was meant to differentiate the spectrum and forms of autism people tended to confuse and overlap interchangeably [50, 51]. Her idea originated within such a naïve, personal context that her first proposal of the term "neurodivergent" was introduced in her thesis

titled Neurodiversity: the Birth of an Idea. The term "birth" underlines the level of discretion she felt to present her idea with, stating that her common association as an autistic subject confused rather than clarified her condition and status. "For me, she explained, "the key significance of the "Autistic Spectrum" lies in its call for and anticipation of a politics of Neurological Diversity, or "Neurodiversity". The neurologically different represent a new addition to the familiar political categories of class/gender/race and it will augment the insights of the social model of disability" [52]. In a nutshell, Singer was proposing a new semiotics of autism, whose socio-cultural associations had taken such derogatory nuances and meanings that she felt she needed to advocate for a new title, name, and dignity. It was however in 1998 that the term spread internationally thanks to American journalist Harvey Blume, who employed the term in a September 1998 issue of the Atlantic, and whose use of the definition eventually turned to be only pioneering [53]. Indeed, the community of neurodivergent individuals did not identify with the interpretation provided by the author – objectified to serve as a metaphor of the internet and its functioning - who however exposed the concept to the wider public, which eventually metabolized it as a new acceptation to address and comprehend statutes falling under the autism spectrum. Celebrating the political, sociological, and medical history behind this term, this thesis will therefore employ it throughout the whole text, complying with international bibliography, new medical descriptory trends, and inclusivity codes. I am however aware that there are several bibliographical schools that question the medical integrity and accuracy of this definition [54, 55], which is however still recurrent in the international bibliography on the topic.

1.3.5 Accessibility and Inclusion within Museum Practices

Definition

Accessibility [56]: "extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use."

Inclusion [57]: "the practice or policy of providing equal access to opportunities and resources for people who might otherwise be excluded or marginalized, such as those having physical or intellectual disabilities or belonging to other minority groups."

Museums globally prioritize enhancing accessibility and inclusivity for visitors with physical or mental health conditions [58, 59]. This involves creating a welcoming and accommodating environment that caters to all visitors, irrespective of their fragility. Strategies employed by museums to accommodate fragile visitors include:

- **Physical accessibility**: ensuring physical accessibility in museums is crucial for individuals with mobility challenges or physical disabilities. It necessitates measures like ramps, elevators, accessible restrooms, and designated parking spaces, enabling disabled visitors to navigate the museum independently and comfortably [60].
- **Sensory-friendly experiences**: visitors with sensory processing disorders or sensitivities may benefit from sensory-friendly experiences, such as dimmed lighting, lowered sound levels, or special exhibitions that are specifically designed [61].
- **Inclusive programming**: many museums are developing programming that is specifically tailored to visitors with physical or mental health challenges. This may include specialized tours, workshops, or interactive exhibits that are designed to be more accessible [61].
- **Training staff**: museum staff may receive training on how to interact with and accommodate visitors who may have different needs due to their fragility. This may include training on how to use specialized equipment or how to communicate effectively with visitors who may have hearing or vision impairments [60].

- **Digital access**: providing digital access to museum collections and exhibits can be particularly beneficial for visitors who may not be able to visit the physical space due to their fragility. This may include virtual tours, online collections, or interactive exhibits that can be accessed from anywhere [62, 63].

By focusing on making their spaces and programming more accessible and inclusive, museums can create a welcoming environment for visitors who may be considered fragile, and ensure that they can fully enjoy and benefit from the museum experience.

1.3.6 Available Digitals Tools for Museum Expiriences

Technology has a significant impact on the way museums showcase and preserve art. However, the use of technology within traditional museums has both positive and negative impacts in terms of management, security and accessibility [64]. Some of the ways in which technology supports museums and their collections include:

- **Digital Collections.** Technology has made it possible for museums to digitize their collections, opening them up to a wider audience via online platforms. This broadens the audience for museum collections, as well as improving their searchability, discoverability, and user interaction with artworks [65].
- **Virtual Tours:** with the rise of virtual reality (VR) and augmented reality (AR) technology, museums can offer virtual tours that provide an immersive experience of their exhibitions and collections. This is especially useful for those who are unable to visit the museum in person [66].
- **Conservation and Preservation.** Thanks to technology, museums can now better protect and safeguard their holdings. For instance, museums use high-resolution imaging technology to examine and document artworks, as well as specialised software to keep an eye on environmental conditions and safeguard objects from harm [67].
- **Interactive Exhibitions:** technology has enabled museums to create interactive exhibitions that allow visitors to engage with the art in new and exciting ways. For example, museums can use touchscreens, audio guides, and other interactive tools to provide additional information and context about the works on display [68].

Overall, technology has had a transformative impact on the museum industry and has helped to make art more accessible, engaging, and preservation-friendly.

1.3.7 Virtual and Augmented Reality

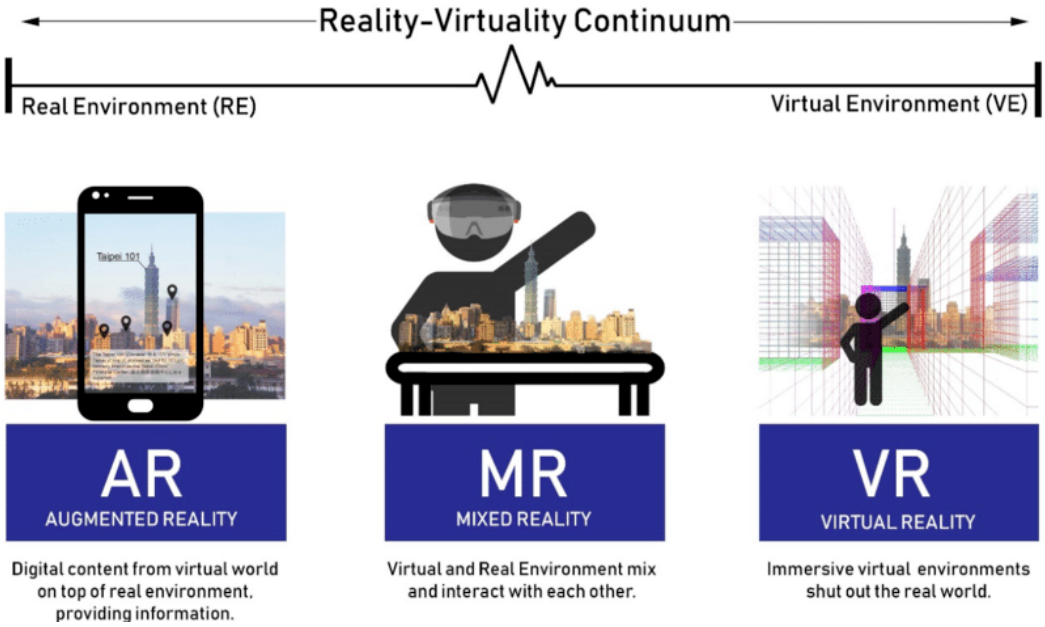


Figure 1.10: Differences between AR, MR and VR [69].

Definitions

Virtual reality "a set of images and sounds, produced by a computer, that seem to represent a place or a situation that a person can take part in" [70]

Augmented reality "is a system that enhances the real world by superimposing computer-generated information on top of it." [71]

The term of extended reality (XR), is the broad umbrella term used to encapsulate all immersive experiences in fully or semi-virtual environments using technologies of AR, MR and VR [72]. The size of the global VR market reached $19.44 billion in 2022 and is expected to surge from $25.11 billion in 2023 to a staggering $165.91 billion by the year 2030 [73]. This growth is driven by the immersive experiences it provides, allowing users to intimately explore virtual scenes from various time periods and locations.

The technologies used range from a common mobile phone, 3D walls to head-mounted displays (HMDs). This makes these technologies applicable to the most diverse contexts, e.g. for education, health, entertainment.

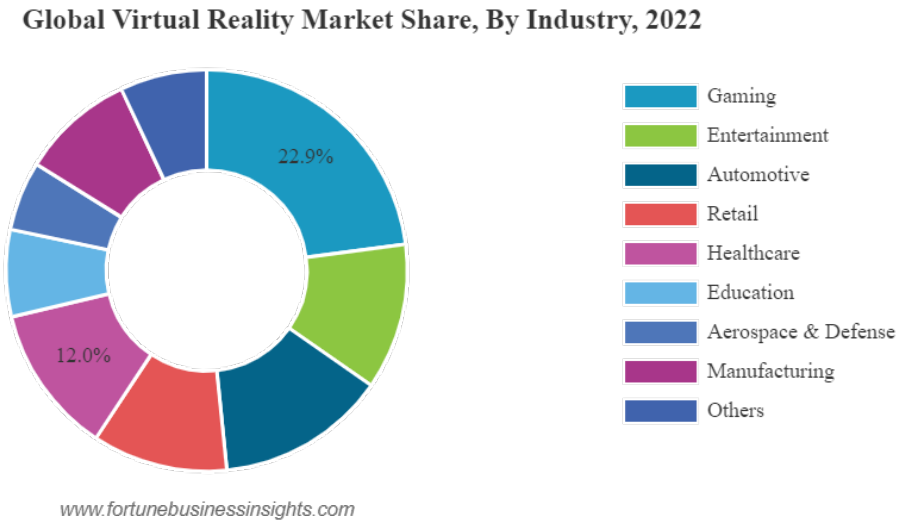


Figure 1.11: The 2022 subdivision of the global VR market shows one-third greater use in gaming and health.[74].

VR has undergone a remarkable journey since its inception and continues to advance at a rapid pace. With major players such as Facebook committing significant financial resources to its growth, the future of VR is not only promising but also teeming with opportunities [75].

Feature	Google Cardboard	HTC Vive Pro 2	Meta Quest 2
Platform	Android, iOS	PC (Windows)	Standalone (Android-based)
Price (Approximate)	$10 - $15	$799 (Headset Only)	$299 (64GB), $399 (256GB)
Display	Smartphone Display	Dual RGB low persistence LCD	Dual RGB low persistence OLED
Resolution Per Eye	Varies (Depends on Phone)	2448 x 2448 pixels	3664 x 1920 pixels
Field of View (FOV)	Typically 90° - 120°	Up to 120°	Approximately 90°
Tracking	Limited (3DoF)	Full Room-scale (6DoF)	Inside-out 6DoF
Controllers	Limited (Depends on Phone)	HTC Vive Controllers	Oculus Touch Controllers
External Sensors	None	SteamVR Tracking 2.0	None
Audio	Phone's speakers/headphones	Integrated headphones	Integrated speakers and 3.5mm headphone jack
PC Requirements	None	High-end gaming PC	None
Content Library	Limited	Extensive	Extensive
Setup Complexity	Very easy	Complex	Very easy
Portability	Very Portable	Not Portable	Very Portable
Comfort	Basic	Comfortable	Comfortable

Table 1.1: Comparison of Google Cardboard, HTC Vive Pro 2, and Meta Quest 2

1.3.8 Building Information Modeling

Definitions BIM

Building Information Modeling: "As an activity, BIM thus consists of the set of processes applied to realize, manage, derive and communicate information between entities at different levels, using models created by all participants in the building process, at different times and also for unequal purposes, to ensure quality and efficiency through the entire lifecycle of the building. Instead, BIM as an object is an unambiguous digital representation ... consisting of digital objects corresponding to real-world components such as walls, doors and windows with associated relationships, attributes and properties." [76]

A significant portion of architecture, engineering, and construction (AEC) projects involve the use of BIM, which calls for a complete shift to digitalization in the manufacturing sector. BIM is a process that involves the creation and management of digital models of a building or infrastructure, and it can be used for design, construction, operation, and maintenance. Unlike the traditional method, Computer Aided Design (CAD), BIM has changed the way project is done [77].

Here are some key points about BIM:

Interoperability

Interoperability, which enables the seamless exchange of data and product information between various software platforms without the loss of essential information, is the cornerstone of BIM. This skill permits thorough and effective collaboration amongst various construction parties. Interoperability should be understood not only between software but also between the stakeholders involved in the process. Interoperability is of two types:

1. **Horizontal**. It concerns consists of the exchange of data between two architectural BIM software, e.g., CAD-to-CAD.;
2. **Vetical**. It concerns architectural and structural software environments, such as the CAD-to-CAE path [78].

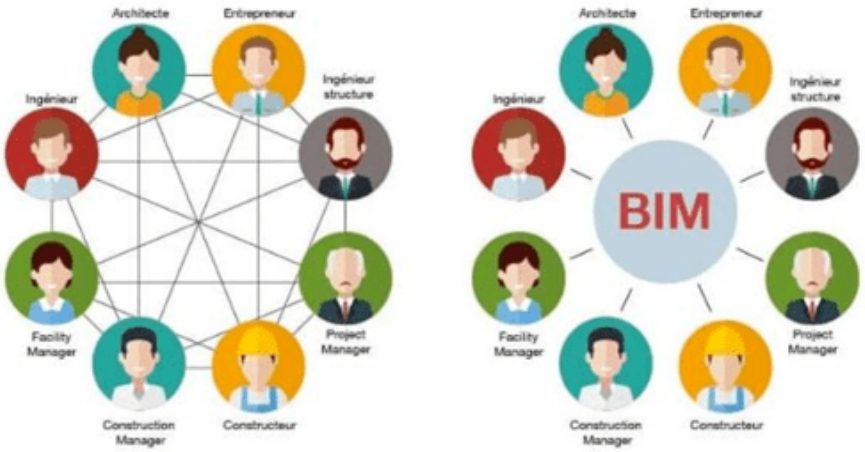


Figure 1.12: Representative diagram of the difference in collaboration between traditional and BIM.

The exchange of data and information can be performed either between software produced by the same company or through the use of plug-ins, which allow the use of proprietary formats. Alternatively, it can be performed between software from different companies, requiring in this case the use of the Industry Foundation Classes (IFC) format as the standard exchange format. The IFC format, developed by buildingSMART, is an open, non-proprietary format designed to facilitate interoperability between different actors. This approach is known as **openBIM** and aims to make the entire process independent of single proprietary formats [79].

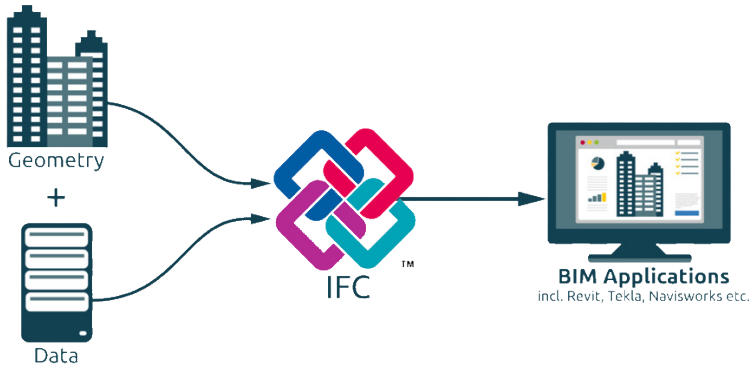


Figure 1.13: IFC file includes both, geometry and data [80].

Industry Foundation Classes

In Italy, the IFC format and conceptual data schema is normalized by the ISO 16739:2013 standard. The structure of the IFC format consists of multiple entities, which can be rooted and unrooted.

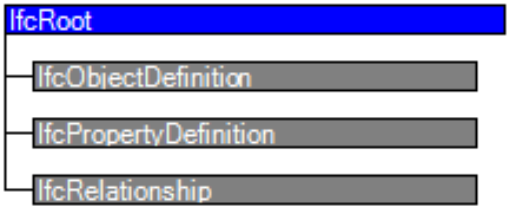


Figure 1.14: Entity inheritance of IfcRoot [81]

The main type of entities are *IfcRoot*, which is the category that encompasses all rooted entities. *IfcRoot* is composed of 3 three abstract categories [81].

- *IfcPropertyDefinition*: defines the concept of aggregating individual properties into a comprehensive set of characteristics that can be assigned to objects.
- *IfcRelationship*: defines the relationships between objects, and these can be 1-to-1 and 1-to-many relationships;
- *IfcObjectDefinition*: defines the presence and types of material objects;

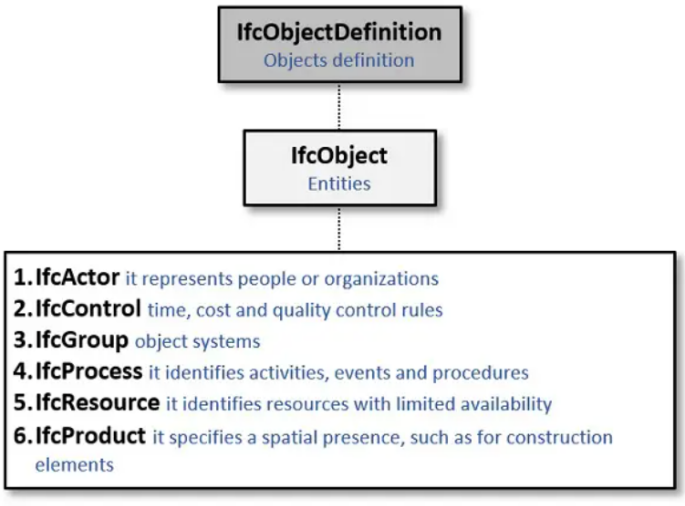


Figure 1.15: Entity inheritance of *IfcObjectDefinition* [82].

All the elements required to provide a thorough description of a construction asset are included in the *IfcObjectDefinition* class. An object is an intangible or abstract thing that represents the description of a part of the building that is being digitally documented. All objects are represented by the *IfcObject* class, which responds to the 5Ws with the following classes: (who) *IfcActor*, (why) *IfcControl*, (what) *IfcGroup*, (where) *IfcProduct*, (when) *IfcProcess*, and (how) *IfcResource*.

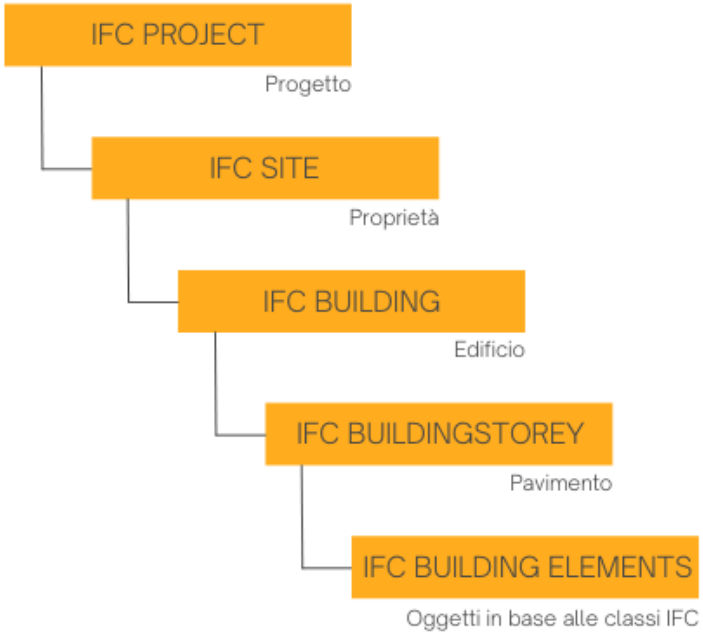


Figure 1.16: Logical description of a single IFC project [83].

The *IfcProject* class is a fundamental entity within the BIM framework that serves as the highest-level container for organizing and managing information related to a construction or building project. Considering the design of a building, the *IfcProject* class representing that building is characterized by: 1) *IfcSite*, that includes a definition of the single geographic reference point; 2) *IfcBuilding*, that is used to build the spatial structure of a building; 3) *IfcBuildingStorey*, typically represents a (nearly) horizontal aggregation of spaces; 4) *IfcBuildingElement* that is an abstract entity and it represents foundation, floor, roof, wall and all object in that aggregation of space [84].

It is important to note that all classes can be linked together through the relationships that act as the glue to define everything within the IFC context.

1.3.9 Heritage Building Information Modeling

Heritage Building Information Modeling, also known as Historic Building Information Modeling (HBIM), is a type of BIM that is specifically tailored to the documentation, conservation, and management of historic buildings and heritage sites [85]. The geometric models derived from the surveys must constitute information representatives, including searchable data covering such aspects as the history and technical characteristics of individual elements, as well as the deteriorated condition of different parts of the work. This rich complex of information must be stored in a database that can be constantly improved over time. The application of BIM to existing construction can increasingly facilitate the disclosure of the built heritage by improving both the methods of data collection and the process of modeling and digital restitution of the object [86]. The growth of the HBIM paradigm in the built heritage sector demonstrates how this approach has enormous potential for improving the building over time in addition to documenting it [87]. However, HBIM currently faces several challenges such as:

- lack of a method that can peculiarly describe HBIM in object parameterization;
- absence of specialized tools for built heritage specialists in the modeling environment;
- a better understanding of information detail accuracy is required [88]

Despite the lack of standards that indicate how to uniquely link BIM to cultural heritage, a key tool for the cultural heritage area is the construction of an open database that defines specific artifacts and their associated qualities [89]. One method proposed for collecting historical information within a museum context is Museum-BIM (MBIM) [90]. MBIM is an external database that collects all historical and cultural data.

Chapter 2

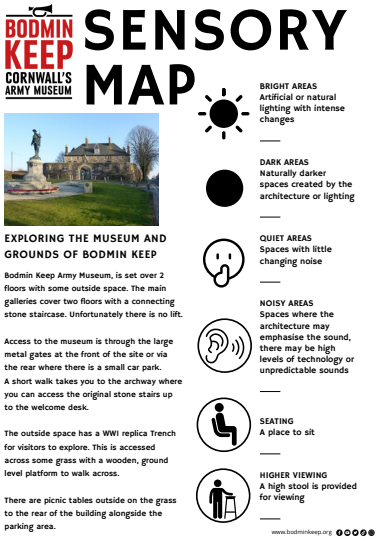
State of the art

This chapter seeks to delve deeper into the intricate relationship between museums and autism, placing a particular emphasis on the transformative power of technology. The analysis focuses on exploring how the integration of mobile applications, VR, augmented reality AR, and BIM technologies can significantly enhance the museum experience for individuals on the autism spectrum. By harnessing the potential of these cutting-edge technologies, museums can create immersive and inclusive environments that effectively address the unique needs and individual preferences of those with ASD.

2.1 International Miscellaneous Case Study & Best Practices

Cornwall's Regimental Museum has undertaken unpretentious modifications to promote inclusivity and encourage visits from individuals with sensory processing disorders [91]. These adaptations encompass the provision of ear defenders to attenuate the intensity of bugle and drum sounds during exhibitions, deactivating hand-dryers in the restroom facilities, adjusting the lighting throughout the museum, and decluttering the reception desk, retaining only essential information. Furthermore, the organization has taken the initiative to offer a social narrative and a sensory map, aiming to enhance the comprehensibility of the site's layout and visiting procedures. see 2.1

(a)



(b)

(c)

Figure 2.1: The solutions adopted by Cornwall's Regimental Museum are: (2.1a) Social Narrative; (2.1b) Sensory Map; (2.1c) Sensory Bag

At **Rijksmuseum**, Saturday evenings are designated for the purpose of hosting Sensory-Friendly Evenings. These events are specially tailored to extend an invitation to individuals who may experience heightened sensitivity or excessive sensory stimulation due to various conditions such as autism, acquired brain injuries, burnout, or illness. During these occasions, deliberate measures are taken to create an environment conducive to accommodating these sensitivities. Within the museum's Atrium, the illumination is intentionally subdued, and the number of visitors is purposefully limited to foster a more comfortable atmosphere. To facilitate the reception process, proficient hosts with expertise in addressing the needs of the target audience are present. As part of the framework for these events, the museum offers complimentary audio tours, enhancing the overall experience by providing informative and engaging insights into the exhibits. Moreover, a selection of the museum's exhibits is thoughtfully curated to ensure sensory-friendly adaptations. This involves considering factors that might mitigate sensory overload, allowing attendees to engage more fully with the artworks and historical artifacts on display[92].

The **Natural History Museum in London** The Natural History Museum in London hosts a recurring complimentary event tailored for children with neurodiverse conditions, known as Dawnosaurs [93]. Knowledgeable facilitators, who are well-versed in understanding and accommodating individuals on the autism spectrum, guide curated tours throughout the museum's galleries and oversee engaging activities. Furthermore, comprehensive social context and pertinent information are furnished to participants prior to their visit, thereby enhancing the overall safety and comfort of the museum experience.

Figure 2.2: Preview of the social history provided by the Natural History Museum of London in PDF format [93].

At the entrance to the **Van Gogh Museum** in the Netherlands, a tangible scale model of the museum itself is positioned. This model serves as a tactile reference for individuals who are blind or partially sighted, allowing them to physically navigate the architectural layout before entering, thereby facilitating their spatial orientation. Additionally, this scale model extends its utility to neurodiverse visitors by providing them with a preview of the museum's spatial arrangement. Mirjam Eikelenboom, an Educator at the Van Gogh Museum, elucidates that the tactile scale model possesses a distinct purpose catering to visitors with diverse visual impairments, yet its applicability transcends and benefits a broader spectrum of visitors. Complementing the museum's tactile representation, concerted endeavors are undertaken to address visitors with heightened sensory sensitivity across the entirety of their museum experience. To achieve this, a dedicated web page has been established to accommodate this audience, aiming to equip them with requisite information. The mentioned online resource serves to prepare and inform these visitors through the provision of several essential elements. Among them are a preliminary visualization of the museum's layout, an accessibility map, guidance on identifying spaces for potential respite, and the option to procure a "Hidden Disabilities Sunflower Lanyard," which can be utilized while within the museum premises. This multifaceted approach not only underscores the museum's commitment to ensuring inclusivity but also reflects their proactive stance in fostering an environment conducive to the needs of individuals with sensory sensitivities [94].

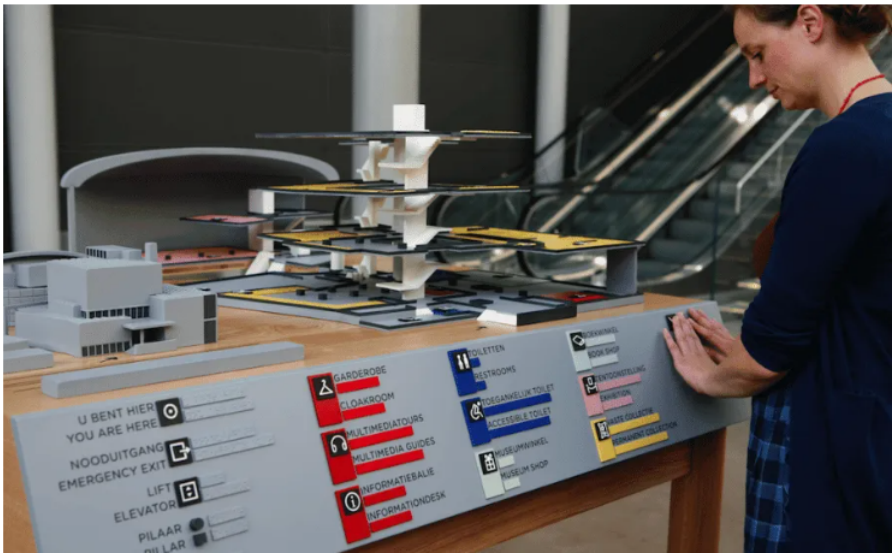


Figure 2.3: 3D model of the Van Gogh museum present at the entrance.

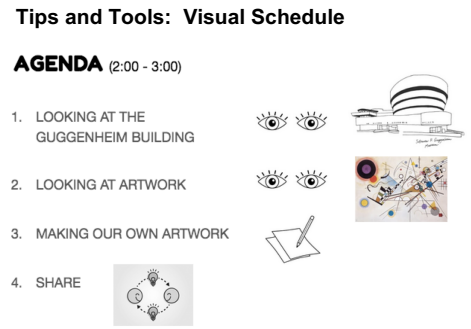
In recent years, the **Dallas Museum of Art**, **Montreal Museum of Fine Arts**, and **Palais des Beaux-Arts** de Lille have all developed programs specifically catered to individuals with autism and other neurodiverse conditions. These institutions, which are part of the FRAME network, have collaborated to create a Guide for Welcoming Museum Visitors with Autism Spectrum Disorder. This guide offers insights and tools for designing mediation activities and spaces that meet the unique needs of visitors with ASD. The recommendations and practical advice featured in the guide are based on the education projects carried out by the three FRAME members, who are part of a larger network comprising 32 museums across Canada, France, and the United States [95].

On **The Metropolitan Museum of Art**'s website, visitors can access a downloadable PDF version of the social narrative for the Discoveries program within the "Resources for Visitors on the Autism Spectrum" section. This narrative is presented in the first person to immerse readers in the program. A sensory map and an interactive map are also provided [96]. see 4.60

(a) **(b)**

Figure 2.4: Some of the solutions adopted by the Met's Museum are: (4.40a) Social Narrative; (4.40b) Sensory Map.

Guggenheim Museum through Guggenheim for All initiative aims to create a welcoming and accessible museum experience for visitors with autism and sensory sensitivities [97]. Some of the resources made available are shown in the figure below.



(a)

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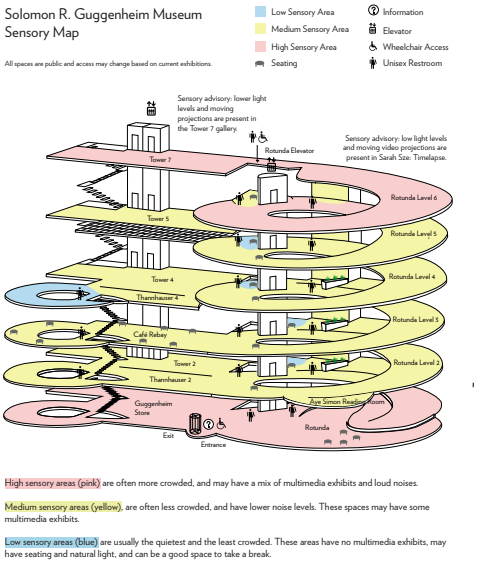


(c)

Figure 2.5: The solutions adopted by Guggenheim Museum are: (2.6a) Visual Schedule; (2.6b) Social Narrative; (2.6c) Sensory Map

Prior to delving into the analysis of the Italian context, it is pertinent to underscore the presence of a singular enterprise, **Infiniteach**. This company currently holds a prominent position within the market, as it specializes in the development of mobile and web app that find application in diverse domains, including but not limited to museums, travel arrangements, and oral healthcare tailored specifically for individuals situated within the autism spectrum. The company's mission is to develop inclusive solutions in the neurodiverse world [98].

(a) **(b)**

(c)

Figure 2.6: (2.6a) Infiniteach company logo; (2.6b) Logo of applications developed for zoos, aquariums, and museums; (2.6c) Mockups of the developed applications showing the interfaces of the developed applications.

2.2 Experiences from Italy Scenario

The case of the **Mart** (Museum of Modern and Contemporary Art) in Rovereto, Italy, exemplifies a pioneering effort in the realm of museum accessibility and inclusion. This institution has made significant strides in ensuring that its exhibits and facilities are accessible to a diverse range of visitors, including those with disabilities. The Mart's commitment to accessibility encompasses both physical and intellectual aspects. In terms of physical accessibility, the museum has implemented various measures such as ramps, elevators, and tactile pathways to ensure that visitors with mobility challenges can navigate the space comfortably. Additionally, accessible restrooms and parking facilities are provided to cater to the needs of all visitors. Moreover, the Mart recognizes the importance of intellectual accessibility. To this end, it has developed innovative strategies (an AAC Guide for visitors exploring its collections) to engage visitors with neurodevelopmental disorders (NDD) and other cognitive disabilities.

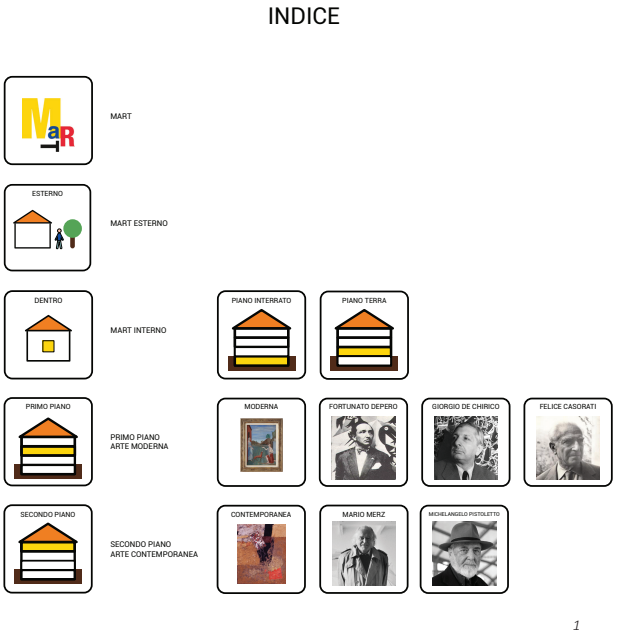
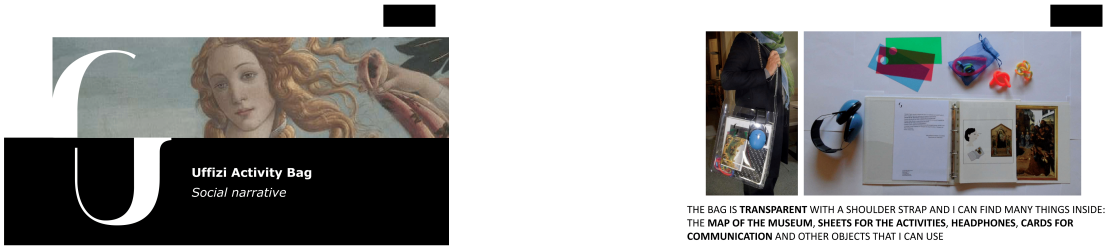


Figure 2.7: AAC Guide for visitors exploring Mart' collections

Uffizi Galleries provides a social narrative to plan the visit and make the museum a welcoming space. It also offers Uffizi Activity Bag containing map, sheets for activities, headphone, cards for communication and other objects.



(a) **(b)**

Figure 2.8: Some of the solutions adopted by the Uffizi's Museum are: (4.40a) Social Narrative; (4.40b) Sensory Bag.

Museums for All is a very interesting initiative that aims to transform traditional social stories into Wearable Immersive Social Stories (WISSs) using immersive technology. Joining this initiative are the **Archeological Museum** in Cremona, La **Venaria Reale** in Turin, the **World Cultures Museum** - D'Albertis Castle in Genoa, and the **National Gallery** in Rome. The design of the WISSs involves the identification and implementation of facilitators and distractors within the virtual scenes created with 360° images [99].

Figure 2.9: Illustrations of a distractor (on the left) and a facilitator (on the right) are provided. The former is represented by a conspicuous, shiny red sphere that is incongruous with the actual environment and, by virtue of its prominence, may divert the user's attention away from traversing the hallway. In contrast, the latter constitutes a Highlight area strategically designed to capture the user's focus and direct it towards the pertinent painting. [99]

2.3 Strategies Employed: Conclusion

After analysing some examples from the world panorama on accessibility for people with ASD in museums, the strategies adopted are summarized in the following table.

Method	**Definition**
Social History (Social Narrative)	Refers to a comprehensive review of an individual's developmental, social, and behavioral background to better understand their unique experiences and needs, often used in diagnosis and intervention planning [100].
Augmentative & Alternative Communication (AAC)	The AAC system offers those who have a language development delay the chance to gain some level of independence, which will enable them to participate in society more fully [101].
Sensory Map	Provides information about the layout of a building and the level of sensory stimulation that may be present in each space.
Sensory Bag	Consists of scientifically validated items that offer comfort and effective concentration for children on the autism spectrum and others who may occasionally experience overwhelm or the effects of traumatic events [102].
Mobile App	Infiniteach develops applications in different contexts, travel organization, museums, zoos and aquariums giving the opportunity to be able to communicate through PACS via its app.
Wearable Immersive Social Stories (WISS)	Fruition of traditional social stories within virtual reality experiences.

Table 2.1: Compilation of strategies used to increase accessibility within museums around the world.

The lack of a methodology BIM, the reduced AR, VR and mobile app approach used with the goal of increased accessibility in the museum context are of relevant importance.

Chapter 3

Case study

3.1 Palazzo Carignano

HISTORY

Palazzo Carignano was built at the behest of Emanuele Filiberto of Savoy-Carignano, to a design by the theatine father Guarino Guarini, who began construction in 1679. It is one of the most evocative and imposing palaces of 17th-century Italy, with a sinuous façade and cladding in simple brick, preciously and originally worked.

The building had been erected in the area used as stables by Prince Tommaso, progenitor of the cadet branch Savoia-Carignano, and originally had a C-shaped plan opening onto the gardens; the current quadrangular structure is due to the addition of the 19th-century building constructed to house the Italian Parliament, and completed in 1871, after the capital moved to Rome. The central elliptical hall in the 17th-century part, formerly used for festivities, was transformed into the chamber of the First Subalpine Parliament in 1848.

Today the palace houses two different museums, as well as the headquarters of the Regional Museums Directorate. On the ground floor the Apartments of the Princes of Carignano reopened to the public in 2011 thanks to the support of the Compagnia di San Paolo. The Appartamento di Mezzogiorno (Midday Apartment) with its marvellous gilded boiseries is permanently open, while the Appartamento di Mezzanotte (Midnight Apartment) and its salons, frescoed by Stefano Maria Legnani known as Legnanino, the talented painter who worked in the Palazzo between the late 17th and early 18th century, are occasionally open to the public. The main floor houses the National Museum of the Italian Risorgimento.

3.1.1 Accessibility analysis

"In terms of accessibility and friendliness, the museum is open all year round, with sporadic nighttime hours and a daily minimum of nine hours. With the exception of December 25, Monday through Friday, and January 1 and May 1, it is open on Saturdays and Sundays. The museum is active on social media and has a separate website that offers general details on hours and services. Any service interruptions or room closures are indicated by the most recent web information. Although there is an admission fee, the ticket counter also acts as a resource for information on the museum and its holdings. Tickets can be purchased at the office with a wait time of less than 30 minutes and discounts are available. Tickets can be reserved at the box office, over the phone, or via email, though they are not necessary unless entrance is free. There are free educational resources accessible at the information point, which is near the ticket counter. Both inside and outside the museum are safety signs, however the latter does not list the name or operating times. There is no reserved parking and no outside signage designating parks and gardens. The reception staff can point to a contact person or give basic instructions to the properties while wearing name tags. With more than 50% of interior rooms, spaces, and services being immediately accessible and 100% of outdoor rooms, spaces, and services being directly accessible, the general population with special needs is given physical accessibility. There is a dedicated personnel on hand, and there are tools and equipment for those who need it, such a stair lift."

This is what can be seen from the Service Charter available on the museum's website [103].

Chapter 4

Materials and Methods

This chapter aims to provide a comprehensive exploration of two primary aspects. Firstly, it will delve into the selection of the software and the specific BIM models that will serve as foundational elements for the development of digital services. Secondly, it will elucidate the methodologies, design principles, and implementation strategies that will be employed in crafting these services.

In terms of the chosen design methodology, this chapter will introduce and expound upon design thinking, a well-suited approach for tackling the intricate challenges at hand. Design thinking stands out as an apt choice due to its inherent emphasis on placing the end user at the forefront throughout each phase of service development, ensuring that the resulting digital services are meticulously tailored to meet user needs and expectations.

4.1 Unity

Unity (frequently referred to as Unity3D) serves as a game development platform and a comprehensive software suite that allows for the creation of interactive media, mainly video games. As stated by CEO David Helgason [104], Unity serves as a comprehensive toolkit for game development, encompassing graphics rendering, sound generation, physics simulation, user interactions, and network connectivity. It is renowned for its rapid prototyping capabilities and extensive publishing options. The objective was to democratize game development, making professional-grade tools accessible to amateur game creators. Unity is a cross-platform engine. While the engine itself presently allows creating games for more than 19 distinct platforms, including mobile, desktop, consoles, and virtual reality, the Unity editor is available on Windows, macOS, and the Linux operating system [105].

4.2 Unity Editor

Thanks to its user-friendly interface, well-conceived architectural design, and the seamless integration of pre-existing assets, the development cycle for 3D software can be significantly condensed in comparison to traditional development methodologies. This newfound efficiency has been further accentuated by the accessibility of consumer-grade virtual reality hardware, which, when coupled with Unity, has recently bestowed hobbyists, professionals, and scholars with the ability to expeditiously craft virtual reality applications. Unity's pervasive adoption and its accommodating interface have led to its full endorsement by several prominent virtual reality companies. Within the Unity editor, the most frequently employed windows include:

- **Hierarchy** contains the list of all *GameObjects* within the current scene.
- **Scene View** provides visualisation and management with the virtual environment constructed within the Editor. Within this view, users have the ability to select, manipulate, and modify *GameObjects*, which encompass various elements such as scenery, characters, cameras, lights, and additional components.
- **Inspector** shows all detailed associated at selected *GameObject* (i.e., Scripts, Colliders, Transform).
- **Project Browser** provides access to and management of the asset loaded in the project.

The version of Unity used for the implementation of the technology services is version 2020.3.42f1.

Unity version
2020.3.42f1

Table 4.1: Version of Unity used.

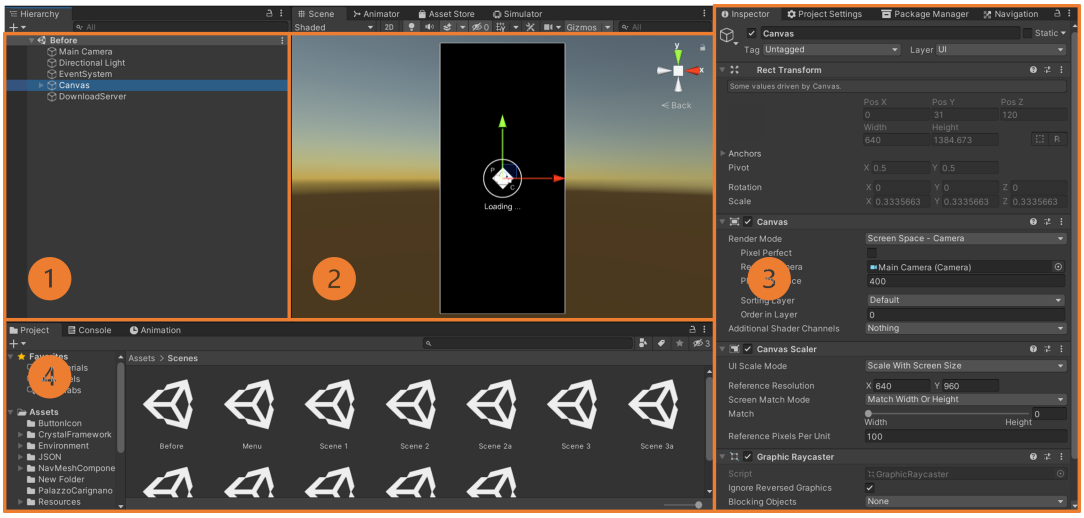


Figure 4.1: Screenshoot of a generic Unity Editor, the following windows are identified: 1) Hierarchy; 2) Scene View; 3) Inspector; 4) Project Browser

The so-called Components that make up GameObjects specify their physical and behavioral characteristics. Each GameObject comes equipped by default with the Transform Component, which depicts the object's position, size, and rotation within the virtual world. Everything that is ascribed to an object is a component, including scripts.

4.3 Unity Engine

Unity Engine is the development engine behind the Editor. Management of Physics, User Interface and Scripting will now be considered.

4.3.1 Physics

Within the context of Unity, the discourse concerning physics engenders an expansive purview. This purview encompasses constituent elements such as Colliders and Rigidbodies, as well as intricate functionalities exemplified by Raycasting. It is of paramount importance to underscore that the orchestration and administration of these resources are underpinned by the NVIDIA Physx physics engine. This engine, conceived and developed by NVIDIA, is distinguished by its remarkable versatility and formidable computational prowess.

Colliders

Unity's colliders handle interaction and collisions between virtual objects. From a visual point of view, they can be seen as the outlines of a GameObject, which determines how the object interacts through its surface with other bodies. From a technical point of view, a collider is the base class, which includes many other classes such as box collider, sphere collider, mesh collider and capsule collider. The box collider, sphere collider and capsule collider all represent box-shaped forms.

These classes show primitive colliders with simple geometric shapes. When using a MeshCollider, things are different. It allows you to create colliders that are based on the mesh applied to the object, which allows for more geometrically complex and accurate colliders, although this requires more in-depth computational calculations.

Rigidbodies

Rigidbodies are a key component of Unity's implementation of physics dynamics for GameObjects, enabling complex behaviors, a variety of joint configurations, and realistic collision responses. It is wise to choose either rigidbody-based physics interactions or direct modifications of the Transform Component when managing GameObjects, avoiding their concurrent use. The main difference between both methods is how they handle forces; rigidbodies can gracefully adapt external forces and torque, giving the GameObject a physics-driven quality. Transforms, in contrast, lack the capability for reliable physics simulations and are primarily intended for translation and rotation.

4.3.2 User Interface

For the creation and management of user interfaces (UI) in games and applications, Unity Engine offers a variety of components. Some of the UI components in Unity:

Canvas

All UI components should be placed inside the Canvas. All UI elements must be children of a canvas, which is a Game Object with a Canvas component on it.

Panel

UI containers called panels are used to gather and arrange other UI elements. They can be used to make pop-up menus, windows, or collections of related items.

Button

One of the most often used UI components is the button. They may be rapidly and easily configured to fit any application and complement any creative style. Publicly accessible on-click capability on buttons enables interactions to be carried out without actual programming. It is also simpler to call custom functions when using buttons.

Text

The Text component allows you to display text on the screen.

4.3.3 Scripting

The primary scripting language used by Unity is C#, which enables control over a variety of features of the *GameObject* and its parts.

Every in-game script should derive from MonoBehaviour, a fundamental class in Unity. It offers several key functions, such *Start* or *Update*, as well as access to the game objects that contain this script as a component. When a script is enabled, Start is called once before the first call to Update methods. If a script is enabled, Update is called once every frame. The *OnGUI* function is used to draw the user interface on the screen and handle GUI (Graphics User Interface) related events. The *OnTriggerEnter* and *OnTriggerExit* functions are used to manage interactions between Colliders.

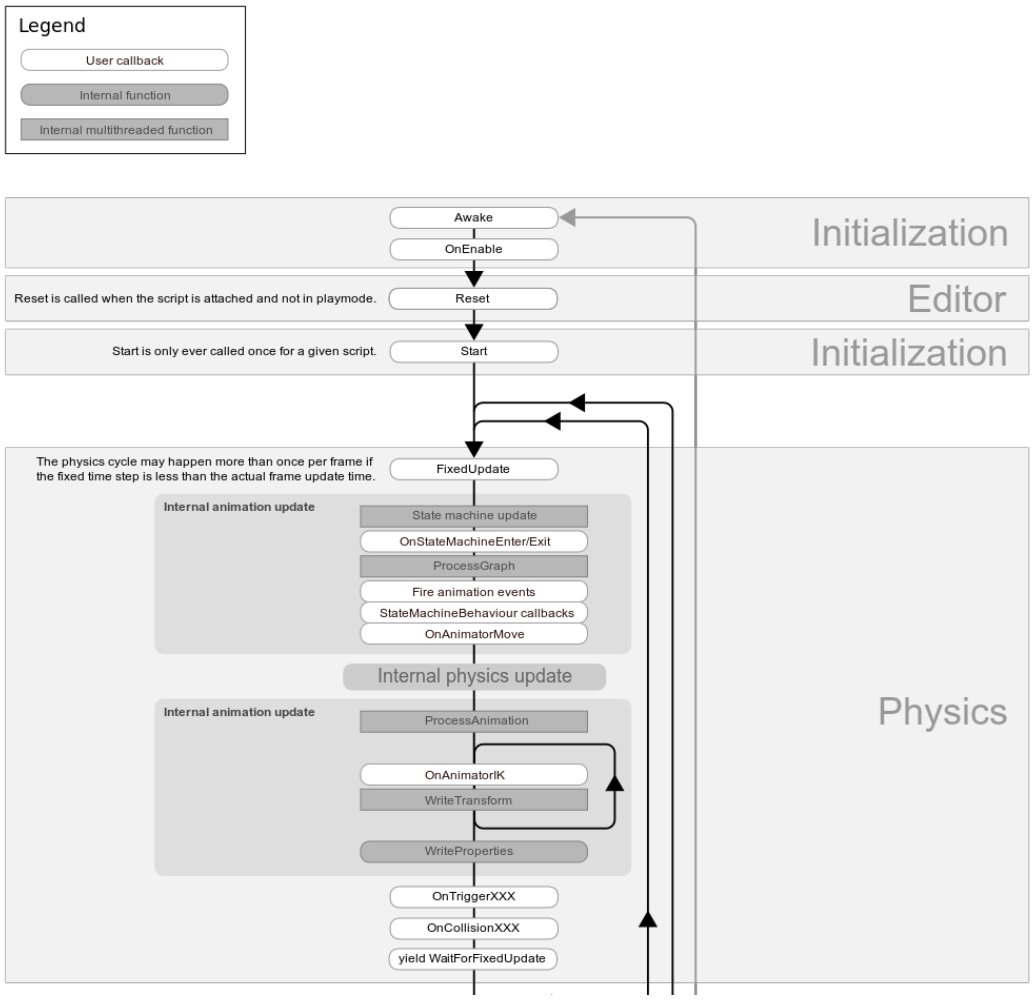


Figure 4.2: Script lifecycle flowchart part no. 1[106].

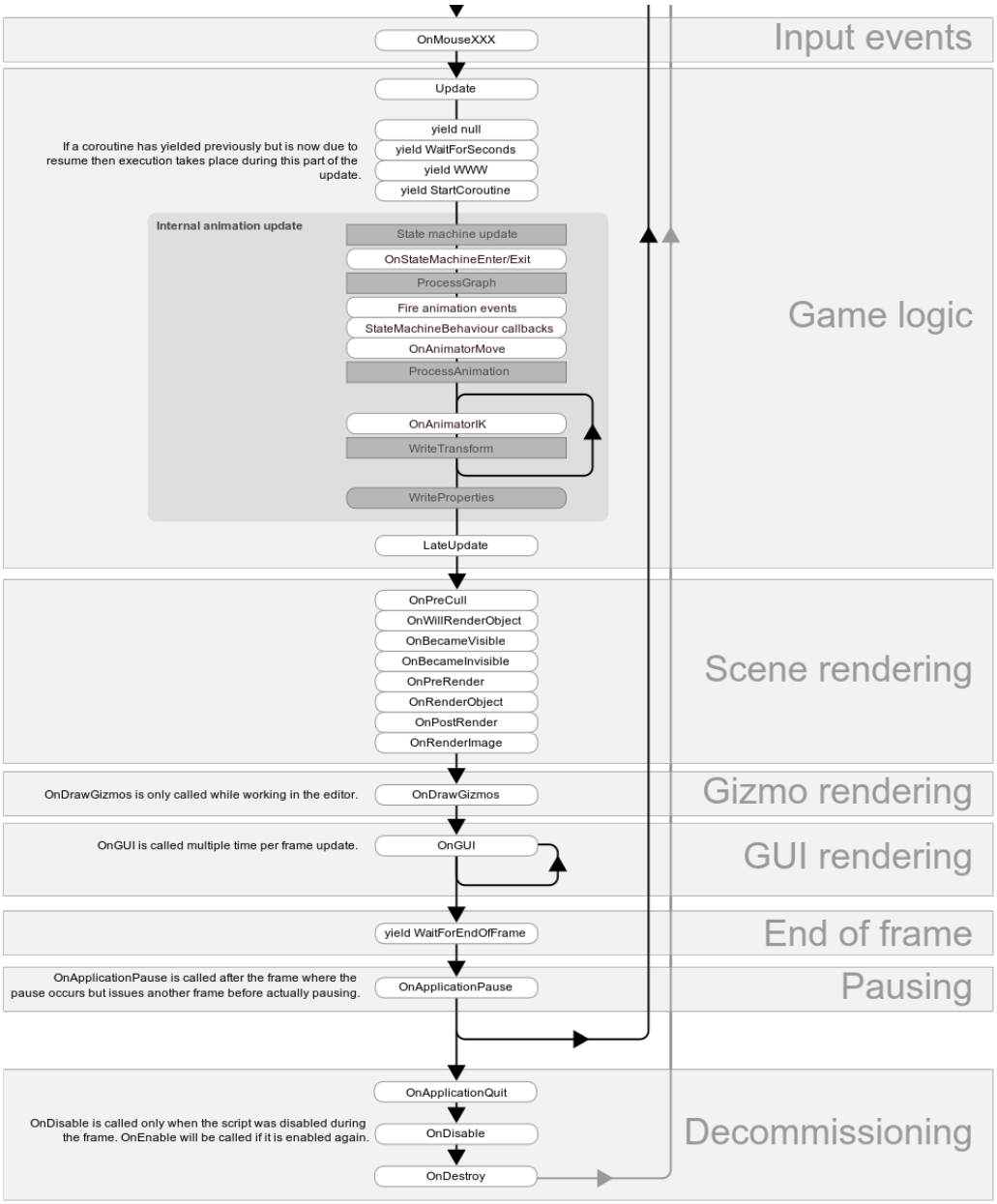


Figure 4.3: Script lifecycle flowchart part no. 2 [106].

4.4 Building Information Model

The BIM model is created using the Scan to BIM methodolgy. The Scan to BIM methodology is grounded in the concept of reverse engineering, which is a process that involves scanning a physical object in 3D and then processing the data using CAD software to create a digital version of the object [107]. Scan To BIM provides 3D point clouds and mesh representations that can be utilized to recreate various elements within a digital environment while preserving all their structural characteristics. These digital representations can then be repurposed in the development of a BIM project.

Laser scanning of a physical environment or building enables the collection of real-world data, which is subsequently imported into a 3D modeling environment to create a point cloud. This point cloud can be used as a basis for generating CAD models or can be directly incorporated into BIM software such as Autodesk Revit. In addition to collecting point data, the 3D laser scanner captures color images, which are employed to create a lifelike 3D representation of the scanned area.

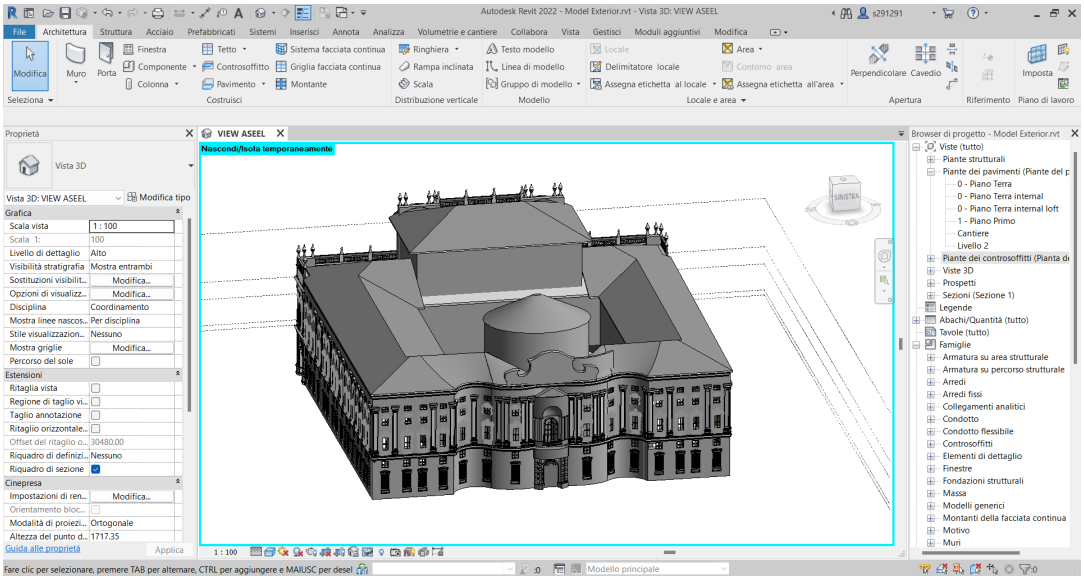


Figure 4.4: BIM model made in Revit version 2020 by Dapino [108].

The file format of the BIM model exported from Revit is IFC; however, this type of format cannot be used in Unity without Unity Reflect. Unity Reflect is a paid Revit plugin that allows BIM models to be used within immersive VR and AR experiences. Therefore, a conversion of the file from IFC format is required to allow a free view version of the BIM model within Unity. The transformation of the IFC file is facilitated through the utilization of the executable software known as COLLADA2GLTF-v2.1.5. This software serves the purpose of converting the IFC file into both eXtensible Markup Language (XML [1]) and Digital Asset Exchange (DAE

[1]The XML constitutes a markup language and file format designed for the storage, transmission, and reconstruction of diverse and arbitrary data. It establishes a set of guidelines for encoding

[2]) formats. In the context of the DAE format, a parameter denoted as "–use-element-guids" is employed to extract the Globally Unique Identifiers (GUIDs) associated with each constituent element within the BIM model.

The gLTF file is a widely used format in the field of computer graphics and 3D modeling. It is an open standard developed by the Khronos Group, specifically designed for efficient transmission and loading of 3D scenes and models in real-time applications [111]. One of the key advantages of the gLTF format is its compactness and efficiency. gLTF files are highly compressed, making them ideal for use in web applications, VR, and AR environments, as they load quickly and consume minimal bandwidth. This efficiency is achieved through techniques like binary data storage and a JSON-based structure for defining 3D models and scenes. gLTF files can contain various components of a 3D scene, including 3D mesh data, materials, animations, and even textures. This comprehensive representation allows for the seamless integration of 3D content into various platforms and applications, ranging from video games to architectural visualization tools [112].

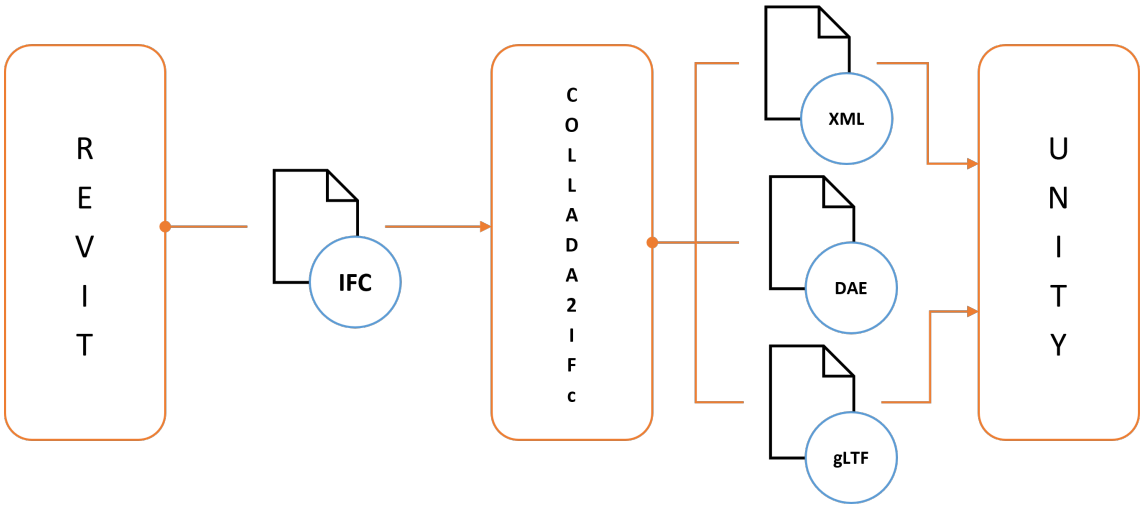


Figure 4.5: Pipline to import the BIM model designed in Revit into Unity. 1) Output file format from Revit: IFC; 2) Output file format from COLLADA2IFC: XML, DAE, gLTF.

To import the gLTF format into Unity, it need to install the **GLTFUtility**, a plugin that allows importing and exporting gLTF files both in the editor and at runtime. However, it requires the installation of the **JSON.NET** package that is

documents in a format that is intelligible to humans while also being comprehensible by machines. XML's foundation can be traced back to the World Wide Web Consortium's XML 1.0 Specification of 1998, which serves as a seminal reference in conjunction with several other interconnected specifications, all of which adhere to the principles of open standards and are freely accessible [109].

[2]A DAE file serves as a 3D interchange file format employed for the purpose of facilitating the exchange of digital assets among diverse graphics applications. Such files may encompass elements such as images, textures, or, most commonly, 3D models. It is important to note that the DAE format is rooted in the COLLAborative Design Activity (COLLADA) XML schema, which is presently under the ownership and ongoing development efforts of Autodesk [110].

a well-liked high-capacity JSON library for .NET and the most commonly utilized library across the entire .NET landscape.

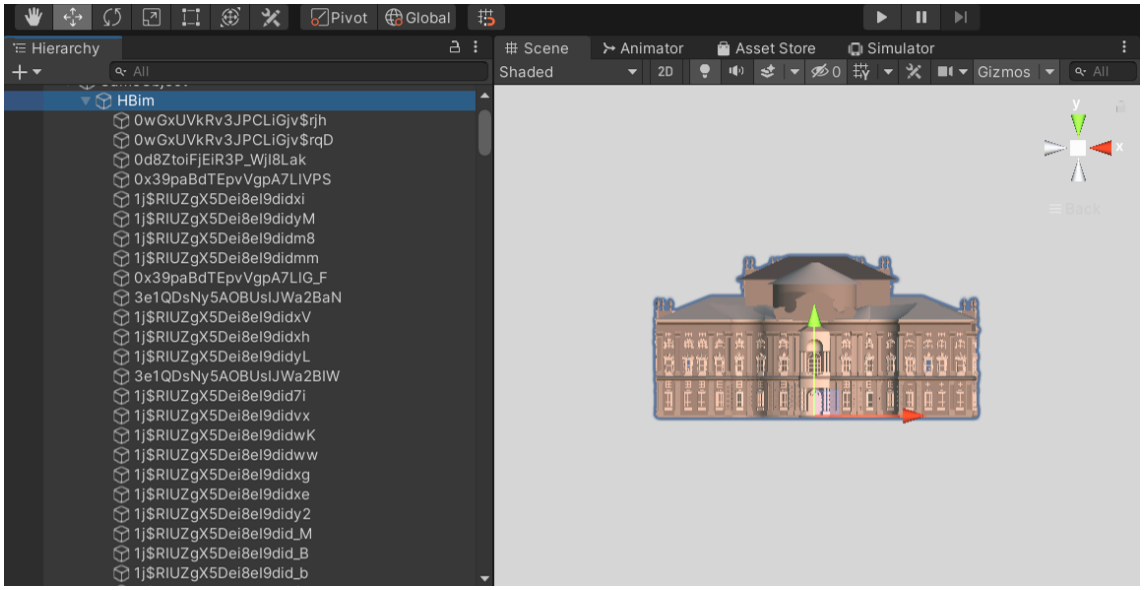


Figure 4.6: Screenshot of Unity showing in the hierarchy the HBim GameObject and its children labeled by their GUIDs.

Nonetheless, when imported into Unity, all the information linked to each instance of the BIM model is forfeited. In order to rectify this limitation, the XML file is employed to reassign each element of the gLTF model in Unity, ensuring that each attribute originally designated in Revit is appropriately linked to it.

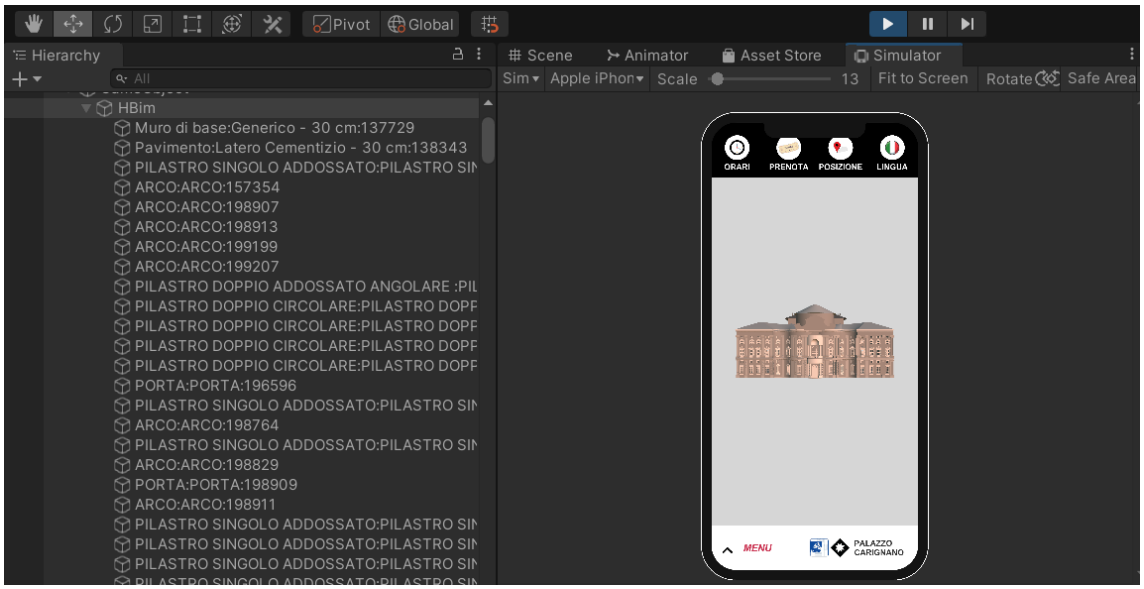


Figure 4.7: Screenshot of Unity showing in the hierarchy the HBim GameObject and its children labeled by their correct name. This is made possible through the C.1 script.

To recreate the essence of BIM i.e., the set of geometry with data, 3 classes are constructed to first identify each IfcBuildingElements, then IfcPropertySet and IfcPropertySingleValue for the properties associated with each IfcBuildingElements. Through the script C.1, the correct instance name and all its properties are associated with each child of the model HBIM using the three classes described above.

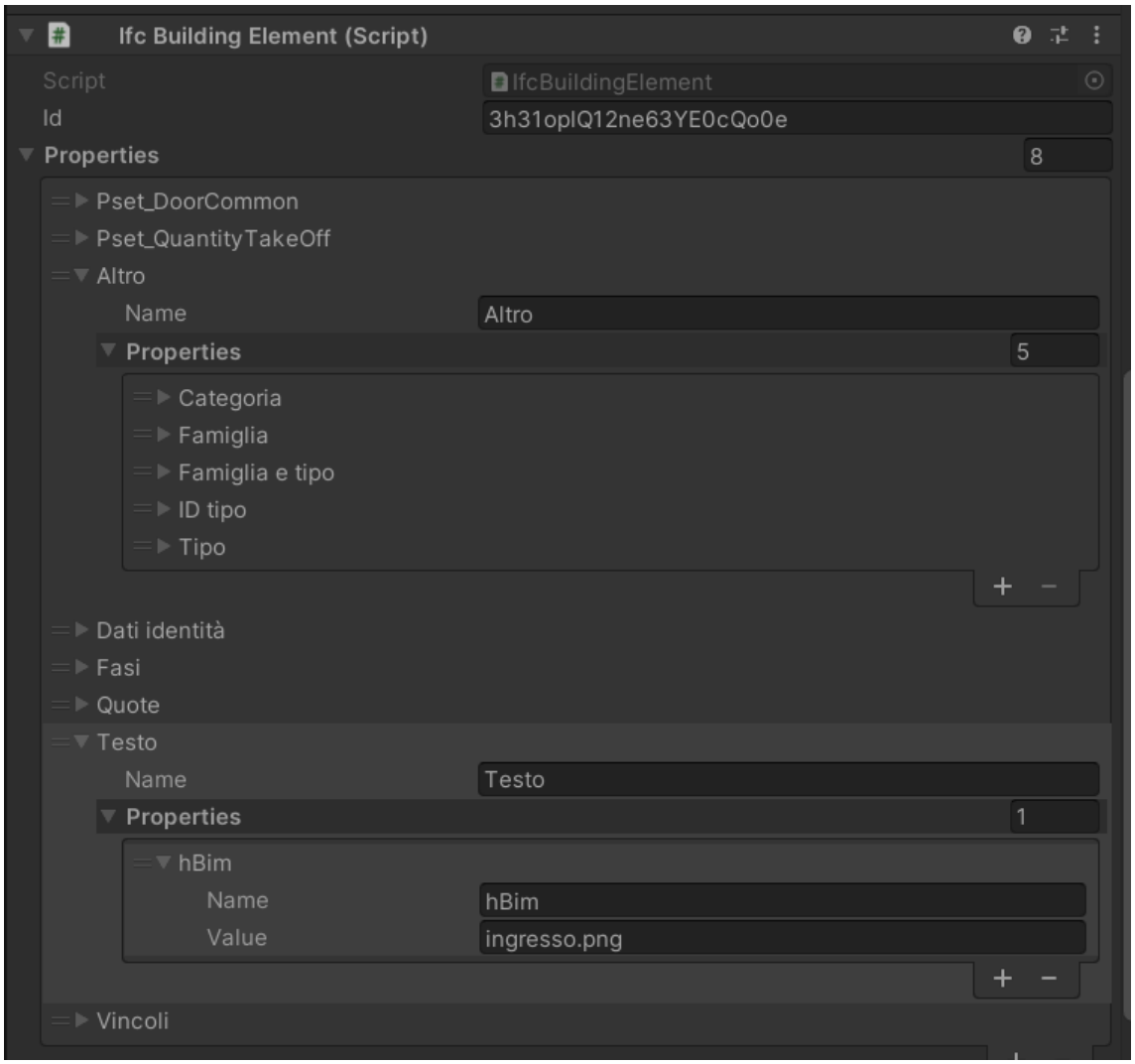


Figure 4.8: Unity screenshot showing in the inspector the IfcBuildinElement class associated with a child of the HBim GameObject.

The key to the data lies in the IfcPropertySet. As a property container, the IfcPropertySet serves to provide project information to all participants and over the entire life cycle of the building.

4.4.1 Heritage Building Information Modelling Application

Described how it is possible to obtain the BIM model in its entirety in a currently non-open application, now it is described how to obtain information related to the

heritage part. Figure 4.8 shows the parameterization of an object using the hBim property, which in that specific case shows the name of a file in png format. However, that parameterization can be used to identify a server API or a link to historical information.

4.5 Design Thinking

Design Thinking is a problem-solving methodology that focuses on understanding users and their needs in order to create innovative and effective solutions. It is a human-centered approach that involves empathy, creativity, and experimentation [113].

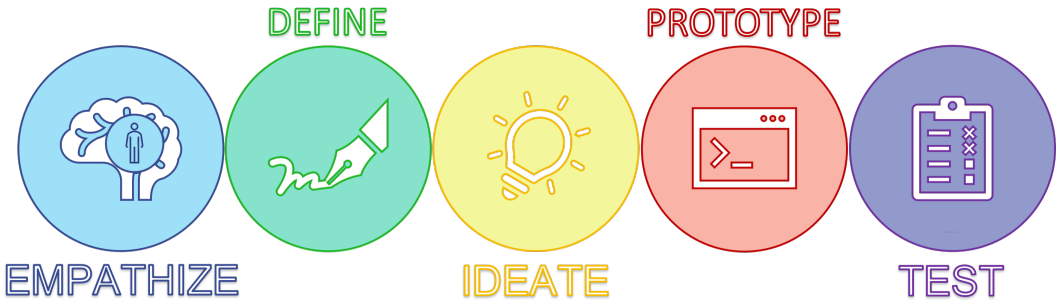


Figure 4.9: Stages of the design thinking approach.

E Through research, interviews, or other data-gathering techniques, this step comprises getting a handle on the needs, ideas, and behaviors of the consumers.

D The problem is identified in this stage by combining the empathy stage's insights and recognizing the major difficulties in light of the information gathered.

I In the ideation stage, numerous potential solutions to the issue determined in the define stage were generated. It was a period of creativity where unorthodox ideas were encouraged to be explored.

P In this step, one or more of the concepts produced in the ideation stage are represented physically or digitally. Depending on the needs of the project, either a low-fidelity or high-fidelity prototype may be used.

T Lastly, user feedback, gathered post-prototype evaluation, informs improvements to better address user needs and the identified issue.

Iterative processes are one of the main tenets of design thinking. As a result, the steps are not always sequential and can be repeated or re-visited to help in

problem-solving [114].

Design thinking can be used in a wide range of settings, from product design and innovation to education and social impact. It is a flexible methodology that can be adapted to suit the needs of different projects and contexts, and it has become increasingly popular in recent years as a way to drive innovation and solve complex problems [115].

4.5.1 Understanding the Human-Needs

In order to understand what the needs of the end-users, subjects with ASD, are, in addition to looking for solutions proposed in the literature in different fields from education to museum settings, it is necessary to understand what stimuli are potentially dangerous for the users. The real environment with all its stimuli (thermal, visual, auditory, tactile), if controlled and designed appropriately for the user, can provide a peaceful experience. Reality understood as the environment in which the user finds himself can be a barrier for the user [116]. Indoor Environmental Quality (IEQ) is not unique for all users. In fact, depending on the type of user, neurotypical or neuroatipical, it can affect their mental state [117].

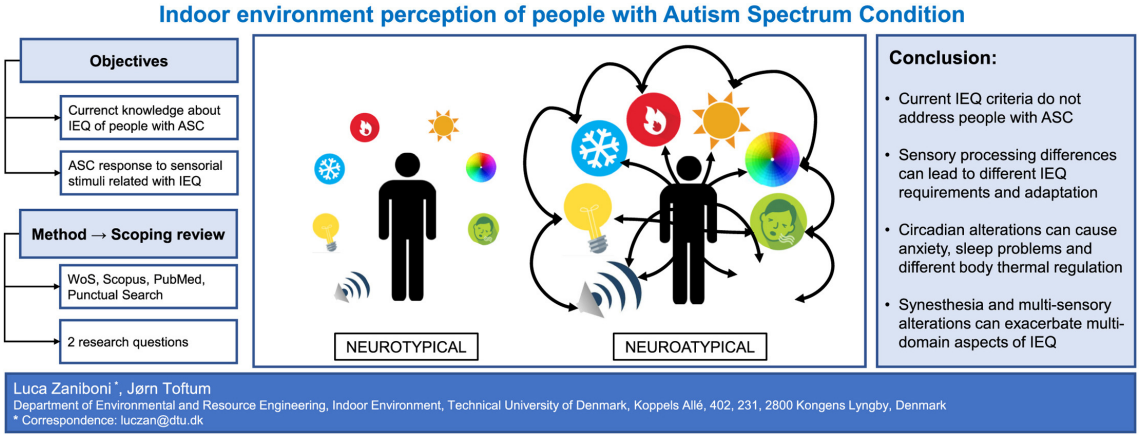


Figure 4.10: This scoping research highlights the significant differences in sensory perception between neurotypical and autistic groups as well as the lack of thorough recommendations for indoor environmental design targeted towards those with ASD. The findings show that more research is required, as well as the development of specialised indoor environmental standards, in order to increase the autonomy, happiness, and health of those with ASD [117].

Technology interposing itself between reality and the user can act as a facilitator.

4.5.2 Define the problem

Before defining the problem it turns out to be important to analyze the process of the museum visit. This process is complex and depends on many variables, such as the type of user and museum. A comprehensive analysis is provided by Recupero et al. who divide the visitation process into 3 major phases and describe them through activity diagrams [118]. The Activity Diagram, based on Young's (2008) Mental Model, identifies innovative design opportunities by mapping users' activities and goals against existing tools and services in the context of museum visits. It highlights key activities and critical tools, crucial for visitors to achieve their objectives [119].

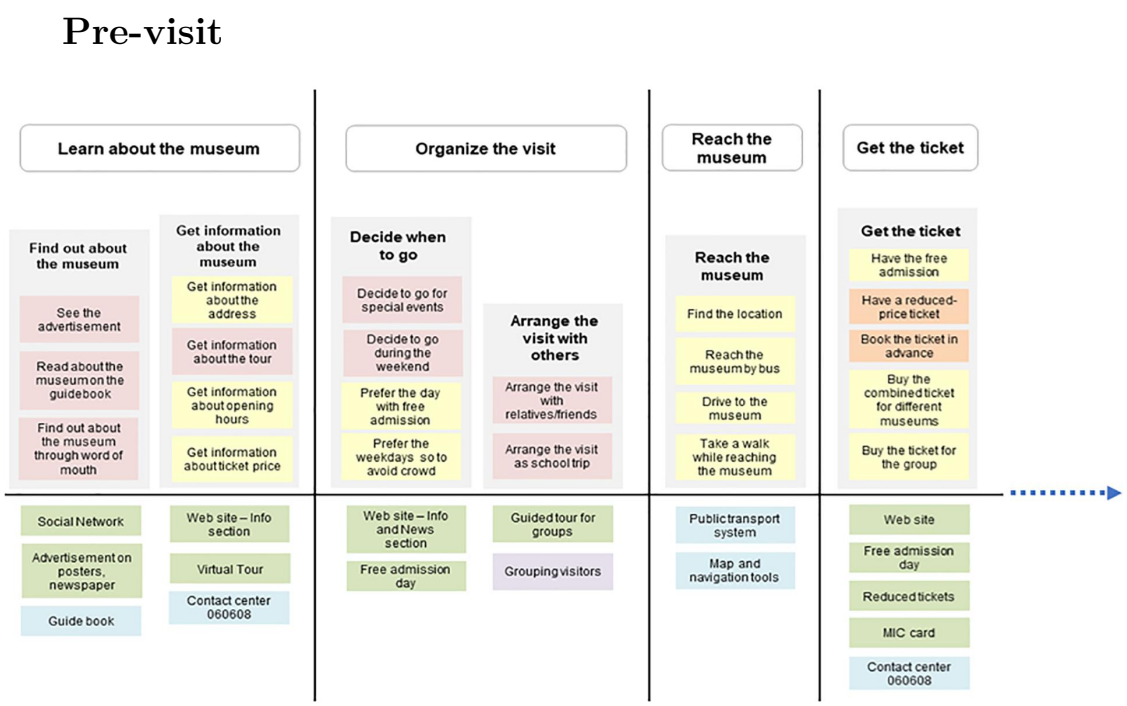


Figure 4.11: The opening segment of the Activity Diagram portrays two key aspects: first, the actions taken prior to the museum visit (such as researching the museum, organizing the trip, reaching the museum, and acquiring tickets), and second, the assortment of services, tools, and information from both the Ara Pacis Museum and external providers that visitors utilize to accomplish these tasks. [118]

Tour

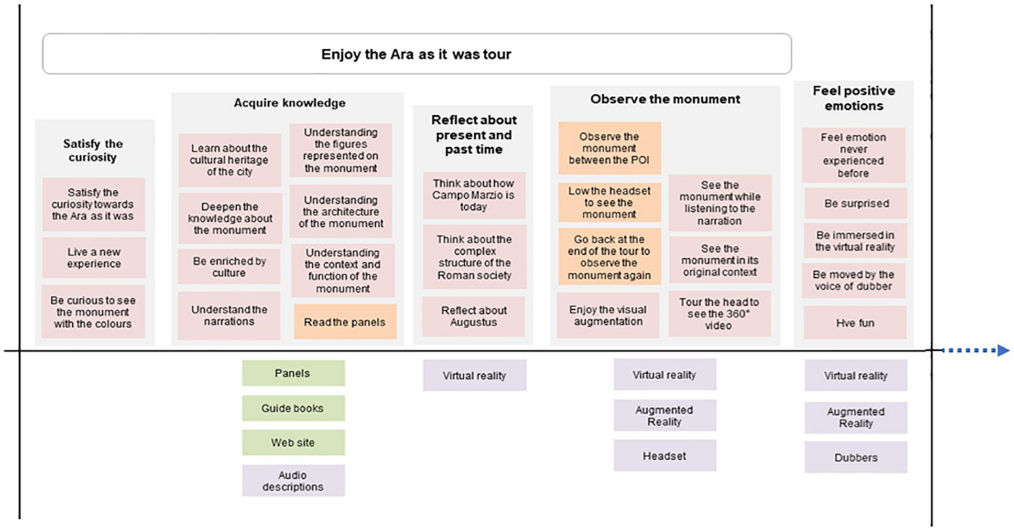


Figure 4.12: The subsequent section of the Activity Diagram illustrates two critical components. In the upper portion, it delineates the central activities during the museum tour, encompassing curiosity satisfaction, knowledge acquisition, temporal reflection, monument observation, and positive emotional experiences. In the lower section, it outlines the characteristics of the "Ara as it was" tour and the ecosystem of museum artifacts that visitors utilize to engage in these activities. [118]

Post-visit

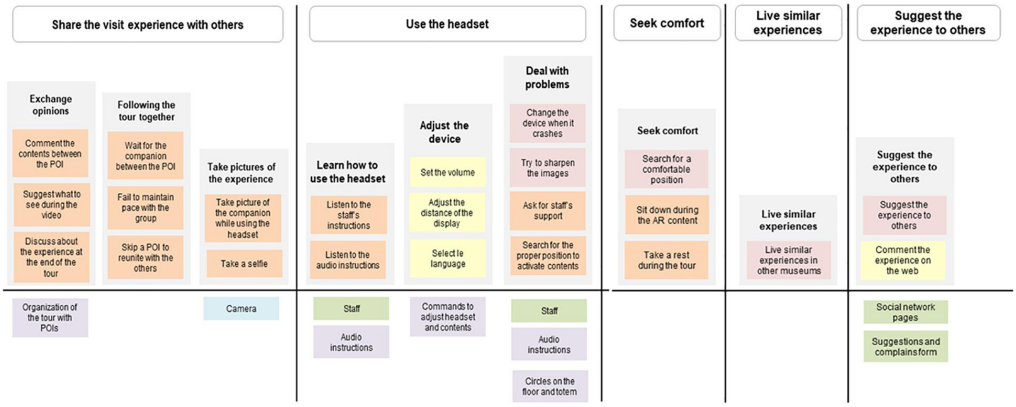
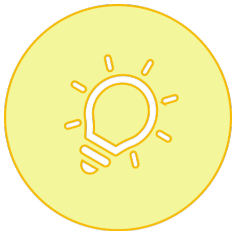


Figure 4.13: The subsequent part of the Activity Diagram illustrates additional key elements. In the upper section, it outlines core activities during the "Ara as it was" tour, including sharing the experience with others, utilizing headsets, and seeking comfort. It also encompasses two activities in the post-visit phase: reliving a similar experience and recommending it to others. In the lower section, it delineates the range of services, tools, and information available from the Ara Pacis Museum and external providers, which visitors leverage to engage in these activities. [118]

4.5.3 Potential Solutions



For each of the steps analyzed earlier, the potential digital solutions to be employed in each step are outlined in the tables below. In the realm of solutions, there are those that have already been executed and made available to the visitors, while others are being implemented and discussed here. The latter category encompasses a mobile application containing the BIM model of the building, videos created through video modeling techniques, elements of AAC present both within the application and within the videos, a prototype of AR, and one of VR.

Pre-visit

By following all the steps outlined in the activity diagram of the pre-museum visit phase(Fig.4.11), it is possible to map out all the potential digital tools and strategies utilized within the context of Palazzo Carignano.

1. Learn about the museum	**Digital Solution**
Step 1.A Find out about the museum	1.1 Social Network 1.2 **Video Modeling**
Step 1.B Get information about the museum	1.2 Website - Info Section 1.3 Contact Museum 1.4 **Mobile App**
2. Organize the visit	
Step 2.A Decide when to go	2.1 Website - Info Section 2.2 **Mobile App**
Step 2.B Arrange the visit with others	2.3 Contact Museum
3. Reach the museum	
Step 3.A Reach the museum	3.1 Map and Navigation tools 3.2 **Mobile App** 3.3 **Video Modeling** 3.4 **VR Experience**
4. Get the ticket	
Step 4.A Get the ticket	4.1 Website - Info Section 4.2 Contact Museum 4.3 **Mobile App** 4.4 **Video Modeling**

Table 4.2: Tools and digital strategies are shown for each step of the pre-visit phase. All **highlighted** digital solutions refer to those that will be implemented here.

Tour

The complete activity diagram (Fig.4.12) adapted for the museum context is also applied during the museum visit phase.

5. Tour of the museum	Digital Solution
Step 5.A Satisfy the couriosity	5.1 Web Site
Step 5.B Acquire knowledge	5.2 Website - Info Section 5.3 **Mobile App** 5.4 **AR Experience**
Step 5.C Reflect about present and past time	-
Step 5.D Observe the monument	5.5 **VR Experience**
Step 5.E Fell positive emotions	5.6 **Mobile App** 5.7 **VR Experience**

Table 4.3: Tools and digital strategies are shown for each step of the tour phase. All **highlighted** digital solutions refer to those that will be implemented here.

Post-Visit

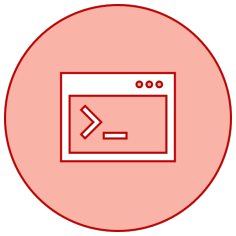
At this stage, only a portion of the activity diagram (Fig.4.13) is being utilized as it is perceived to be less aligned with the context of the Palazzo Carignano museum.

6. Share the visit experience with others	Digital Solution
Step 6.A Exchange opinions	6.1 **Mobile App**
Step 6.B Take pictures of the experience	6.2 Social Network

Table 4.4: Tools and digital strategies are shown for each step of the post-visit phase. All **highlighted** digital solutions refer to those that will be implemented here.

4.6 Video Modeling

In the context of teaching social skills to individuals with ASD, video modeling is one of the interventions. Several studies demonstrate the effectiveness of using video modeling either on its own or in combination with social stories, another type of intervention [120, 121, 122]. To create the forthcoming videos, Powtoon is the chosen video creation tool. These videos simulate the process of visiting the museum, all the way up to requesting museum maps at the ticket counter, with the aim of producing videos suitable for video modeling purposes. In order the modeled videos are 9.



- **Introduction Video**: through gamification, 3 missions are shown with the intention of making it clear *why* 4.15, *when* 4.16, and *how* 4.17 to visit and reach the museum.

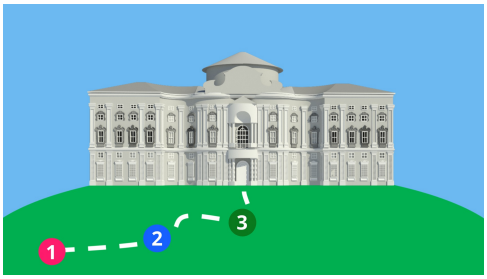


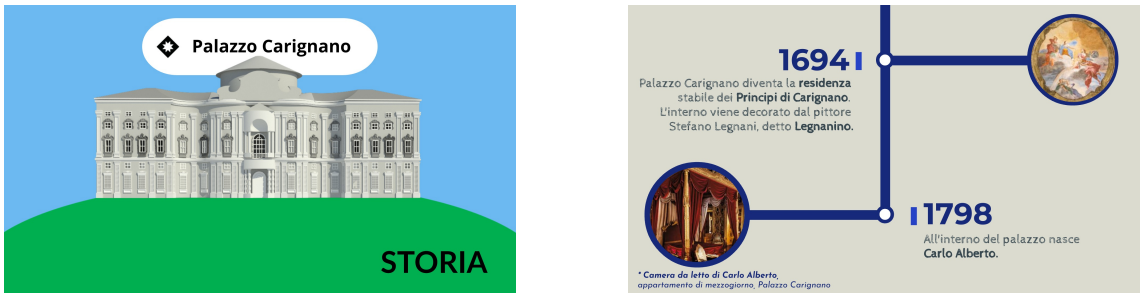
Figure 4.14: Video introductory frame.

Figure 4.15: 1st mission: *Why* go to Palazzo Carignano?

Figure 4.16: 2nd mission: *When* to go to Palazzo Carignano?

Figure 4.17: 3rd mission: *How* to reach Palzzo Carignano

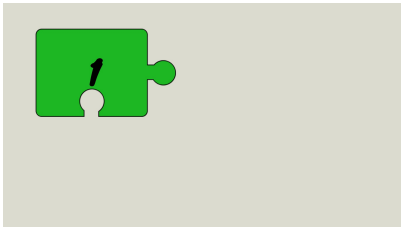
- **Historical Video** (V0) shows the history through images and text of events and personalities that characterize Palazzo Carignano from its birth to its current use.



(a) **(b)**

Figure 4.18: (4.18a) Video introductory frame; (4.18b) Timeline of the history of Palazzo Carignano.

- **Video 1** (V1) illustrates how to reach Palazzo Carignano, highlighting the buildings that characterize the city of Turin.

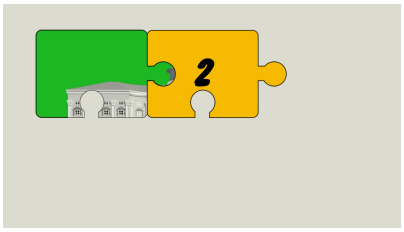


(a)

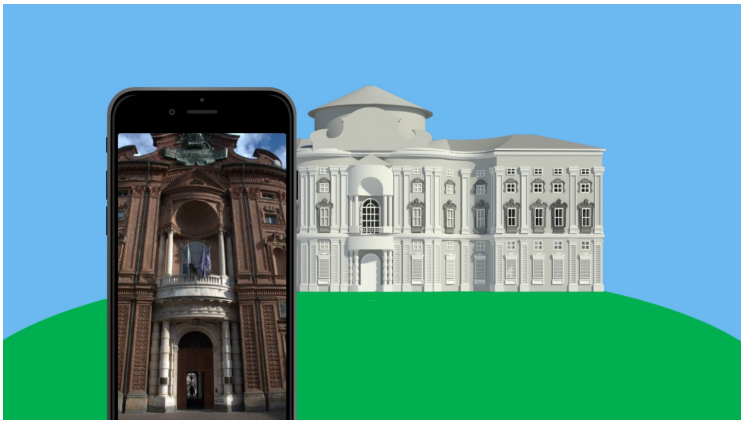
(b)

Figure 4.19: (4.19a) Video introductoy frame; (4.19b) Example of a possible route to the museum.

- **Video 2** (V2) brings attention back to the exterior of the building.



(a)



(b)

Figure 4.20: (4.20a) Video introductory frame; (4.20b) Example of a photograph of the building.

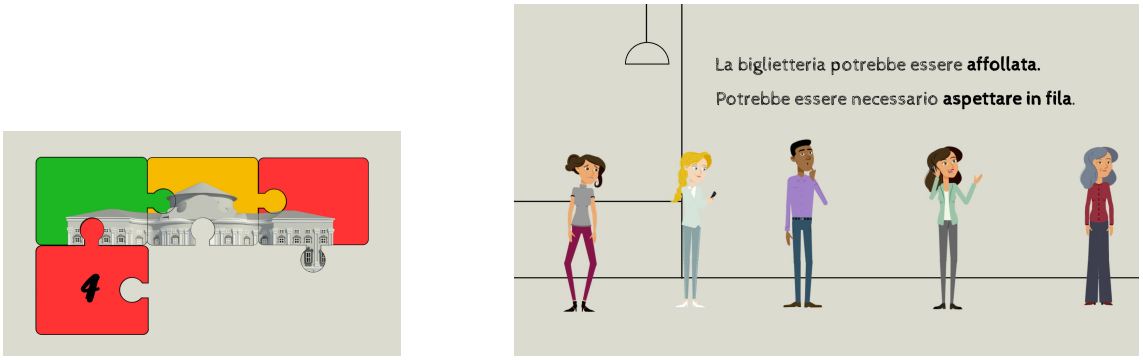
- **Video 3** (V3) shows where the museum entrance is located.

(a)

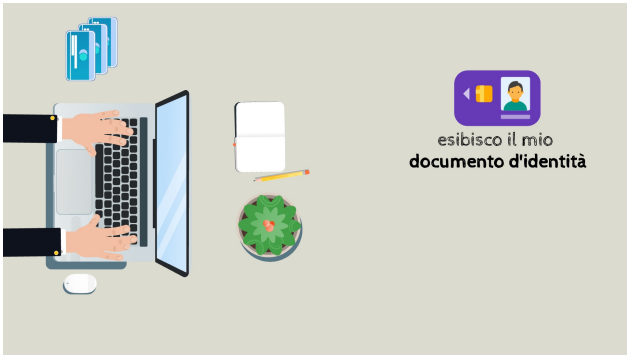
(b)

Figure 4.21: (4.21a) Video introductory frame; (4.21b) The character shows what the entrance is.

- **Video 4** (V4) shows where the ticket office is located and how to get there. It also simulates the action of purchasing a ticket and what element is required to purchase the ticket.



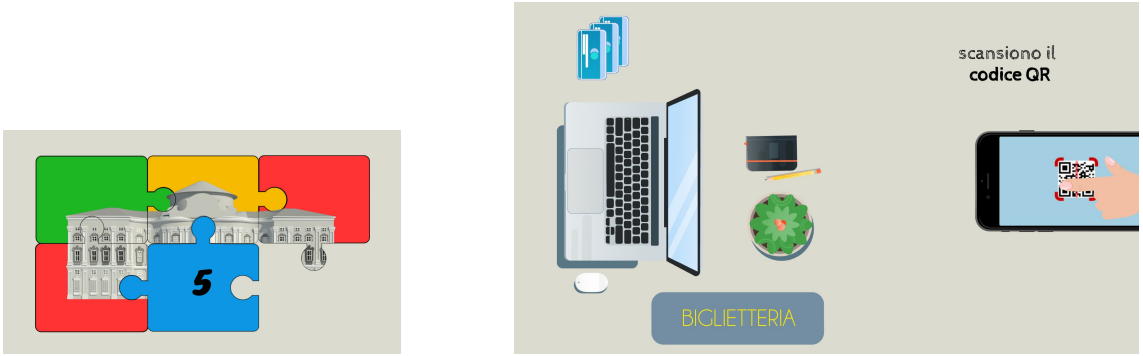
(a) (b)



(c)

Figure 4.22: (4.22a) Video introductory frame; (4.22c) Show what is required to receive the ticket.

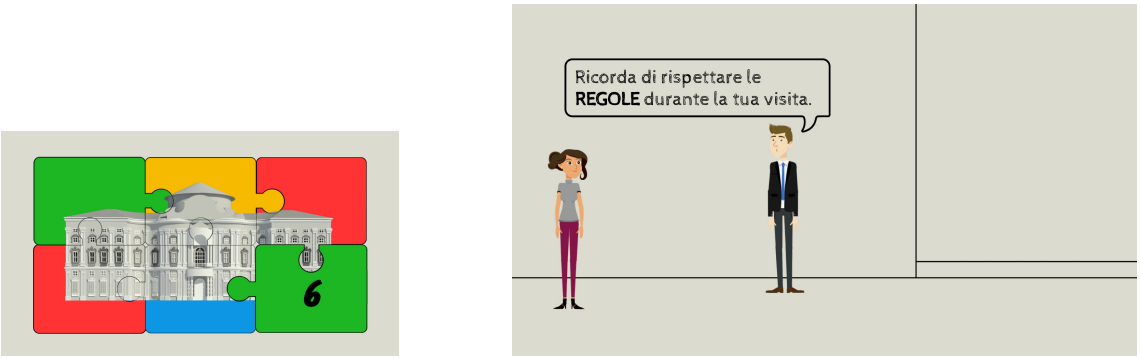
- **Video 5** (V5) indicates to request the museum map with the goal of having a spatial reference during the visit.



(a) (b)

Figure 4.23: (4.23a) Video introductory frame; (4.23b) Shows how to access the museum map.

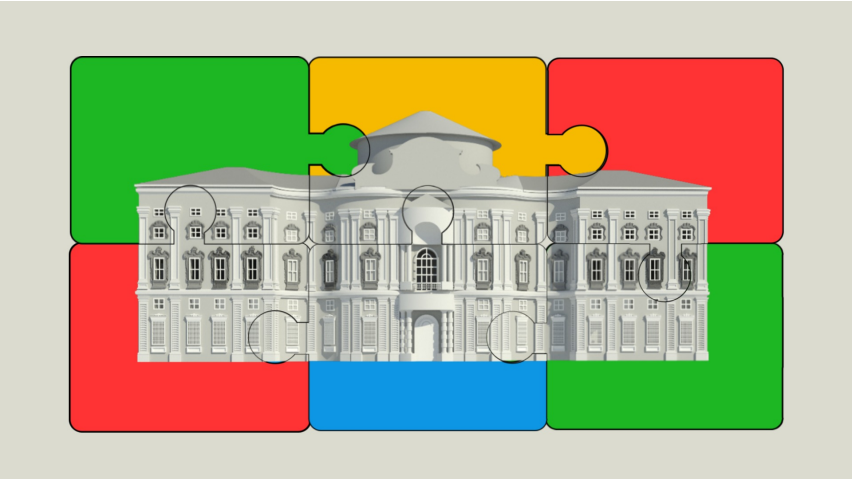
- **Video 6** (V6) shows how all goals were achieved before the visit, but brings compliance to the user's attention.



(a) **(b)**

Figure 4.24: (4.24a) Video introductory frame; (4.24b) It shows an adept indicating to comply with the rules.

- **Video 7** (V7) advises the user to use the routes section of the application during the visit.

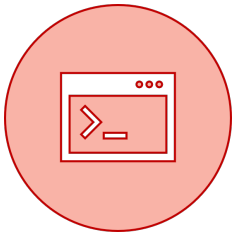


(a)

Figure 4.25: (4.25a) Completed puzzle

The inductive video will be uploaded to a social network, allowing users to access its content. Meanwhile, videos spanning from V0 to V7 are stored on Google Drive and will be fetched by the application at runtime.

4.7 Mobile App



The primary objective of the application is to offer a service that facilitates museum access for neurodivergent individuals. In addition to offering alternative methods, which are often not found in traditional museum settings, such as social narratives, this application also provides standard museum services. These services encompass tasks like checking museum opening and closing hours, verifying ticket prices, and accessing audio guides.

To properly design the application, first the users who interact with the application are defined, from end users to museum staff. By defining the users, the application can be monitored throughout its life cycle. Next, the platforms through which the service can be made available are analyzed.

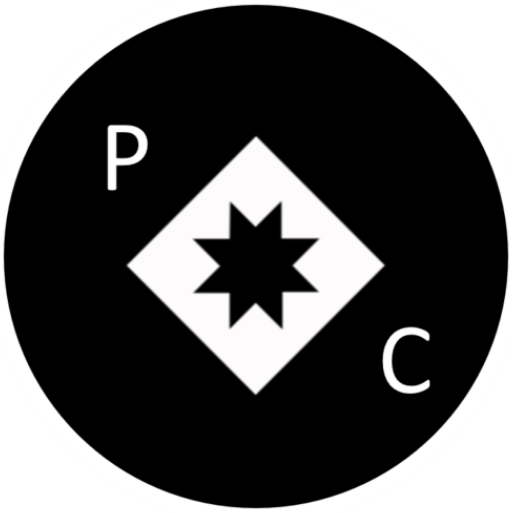


Figure 4.26: Mobile app logo. The museum logo is used for the application logo and in addition the diagonally placed initial is also used.

Text serves as a foundational element within the user interface (UI). It serves the purpose of annotating diverse interactive components and delivering prompt context-specific assistance. As previously discussed, individuals with ASD commonly encounter challenges with reading comprehension. Therefore, the presence of a complex UI containing numerous text segments can hinder usability. It is crucial to structure textual UI elements thoughtfully to mitigate potential reading difficulties [123]. Text content is often associated with icons so as to identify the action that will bring that click.

4.7.1 Use Case Diagram

Official Definition of "Use Case Diagram" from IBM

"In UML, use-case diagrams model the behavior of a system and help to capture the requirements of the system. Use-case diagrams describe the high-level functions and scope of a system. These diagrams also identify the interactions between the system and its actors. The use cases and actors in use-case diagrams describe what the system does and how the actors use it, but not how the system operates internally" [124]

As evidenced by the definition above the use case diagram identifies use cases and actors and how they interact with each other and the system itself. The use case diagram in figure 4.27 shows the actors involved with the system. On the right are the human actors, such as end users, while on the left are the non-human actors, such as Google Drive and Google Translator. Google Drive acts as a server to request the data needed to compile the application properly, while Google Translator is used as a service to request audio files. The request response paradigm is used to request files via the free API.

However, the actors that interact with the management, maintenance of Google Drive data are different and will be described that sub-chapter below.

Regarding the use cases, they are categorized into four major areas. First, there is the loading process, which entails the retrieval of files related to museum management from Google Drive. Next, we have the application homepage, which is designed with the objective of displaying the BIM model of the building and granting access to all subsequent services. These services are further classified according to the type of data they use. Blue groups all use cases that use data related to museum management, while red groups those related to historical and artist data. A detailed description of each use case will follow in Chapter 4.7.3.

Figure 4.27: The use case diagram shows the actors involved with the system. On the left (human actors) the generic user using the application; on the right (non-human actors) are Google Drive and Google Translator. Also shown are the use cases that characterize the application divided according to the types of data they use.

4.7.2 Actors: Need to Integrate the Application Into a Practical Context

To integrate the application into a practical context and prevent the need for a technician or Information Technology (IT) personnel to recreate an executable of the application even for minor historical content changes, a decision has been made to segregate the historical/artistic content component from the programming component. To do this, it has been decided to use a Google Drive as a server to store all the data that the application needs for completeness. The application retrieves files based on their identifier (ID), which simplifies the work of all museum departments during maintenance. The Google Drive is structured into three distinct folder categories. (see fig.4.28).

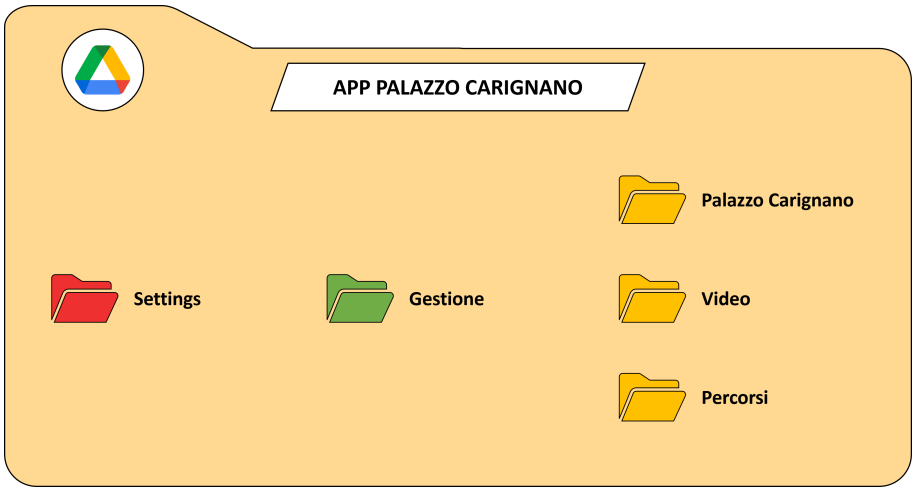


Figure 4.28: Structure of Google Drive provided to users.

These types are as follows:

1. **Settings**. This folder organizes the files in JavaScript Object Notation (JSON) format IT_handling, video, paths and path_i. This folder has been designed for those in charge of the museum's IT area.

    - The **IT_handling** file associates the properties address, mobile, mail, weburl, timetable, price, and the GoogleForm url with the values corresponding to the file ID present within the same drive.
    - The **video** file organizes for the four languages (Italian,English, French, and Spanish) and for each language the videos within the application are proposed with their IDs that are downloaded while running the application.
    - The **paths** file contains the properties midday path, midnight path, and staircase. These three properties is the actual museum subdivision within the museum.
    - The generic file **path_i** contains within it as many properties as there are

areas to be visited, and each property is associated with a value corresponding to the text file (brief art historical description) that will represent that area.

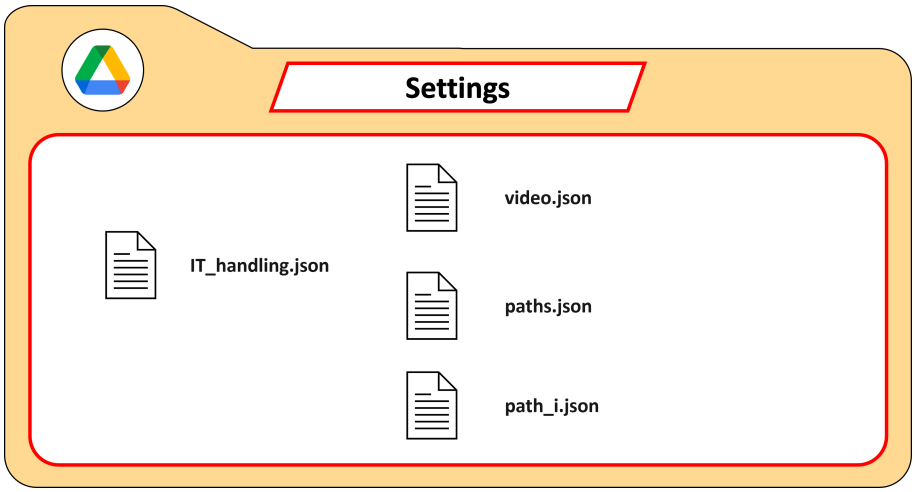


Figure 4.29: Structure of settings folder.

2. **Managment**. The folder in question contains all files related to the management of the museum both from the physical point of view such as opening and closing times, but also web address of the museum. This contains all the files indicated in the IT_handling section described above and has been designed for users in the museum management area.

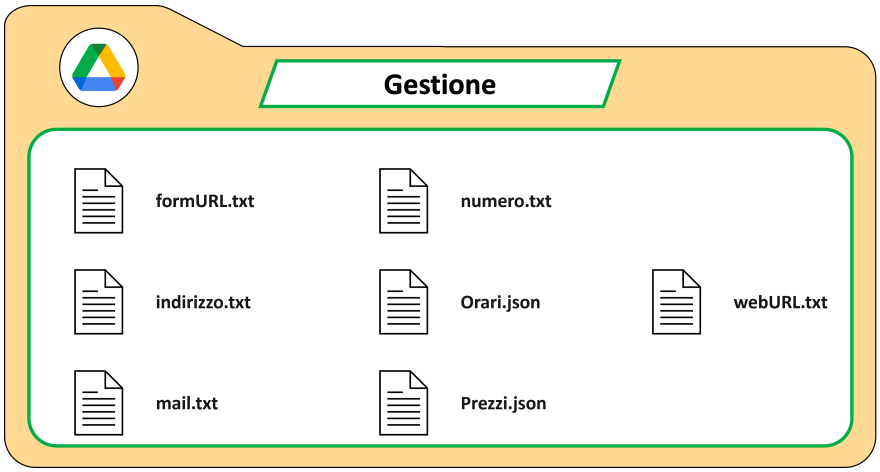


Figure 4.30: Structure of management folder. This folder contains files in text format of formURL, webURL (related to website), address (Google Drive link), email and mobile number useful for reservations. While the Schedules and Prices files are in JSON format.

3. **Multimedia content**. This category includes all components associated with the multimedia content that is displayed within the application, for example, such as videos made using the video modeling technique, text containing descriptions of individual rooms, or general descriptions of the Palazzo. The category consists of three folders, respectively, video, Palazzo Carignano and "Percorsi". Figure 4.33 shows the organization of the "Percorsi" folder to which the Palazzo Carignano folder also refers. Within each room-specific folder are 4 files each for each language in which the application is available. Access to these types of folders has been provided for those within the museum who have the art historical skills.

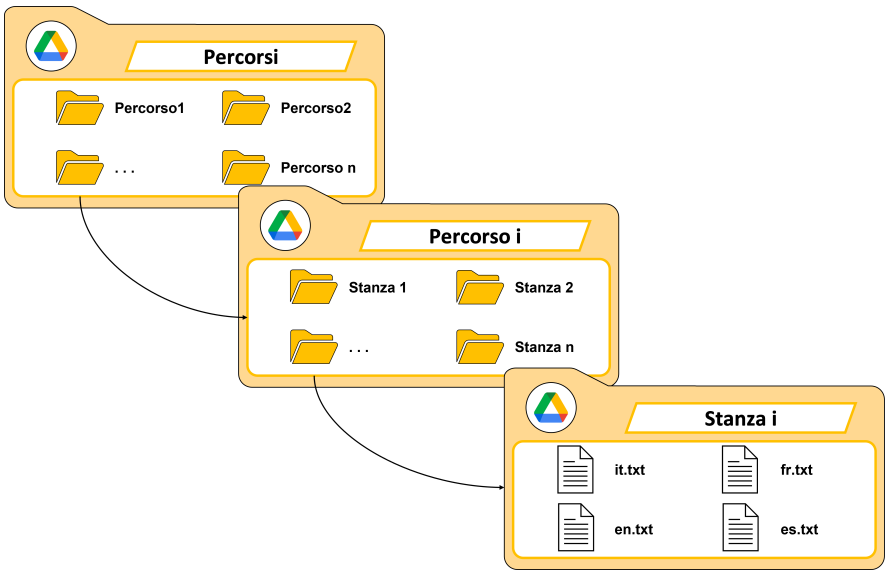


Figure 4.31: Structure of paths folder. The Palazzo Carignano folder is similar to room i.

To prevent the application from becoming obsolete due to incorrectly defined schedules, description updates, or other issues, comprehensive guides are distributed to each operator. These guides aim to ensure the application remains current and provide instructions on the correct procedures for making updates. The guides can also serve as an access tool for the museum itself, enabling it to autonomously integrate an application maintenance program into its operations. The appendices A and C includes the following guides.

4.7.3 Description of Use Cases

The primary objective of this application is to offer a comprehensive suite of museum services through digital means, featuring user-friendly and intuitively designed interfaces specifically tailored for individuals within the ASD. In addition to presenting the museum's artistic and historical collections, the application is intended to encompass information pertaining to museum administration, as well as its operational hours of operation.

To realize the entire application, 8 scenes are made in Unity. In order, the **Before** scene used to download files via the Google Drive API. The **Home** scene representing the main page of the application from which it is possible view and interact with the BIM model of the Palazzo.

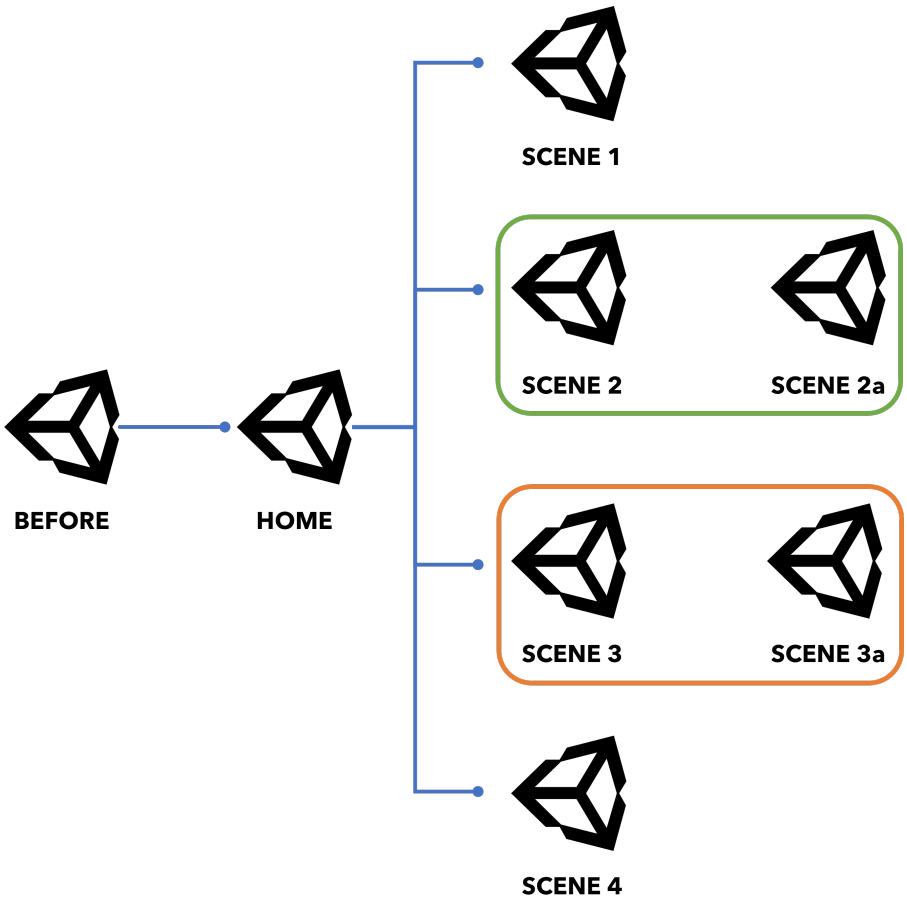


Figure 4.32: Links between scenes in Unity handled via the C.2 script. (Green) Scene 2 and Scene 2a represent the same functionality but provided in 2 different ways, one in text format, the other through the use of AAC. (Orange) Scene 3 and Scene 3a related to the paths section.

From the home via a drop-down menu it is possible to go to the other functionalities:

- Palazzo Carignano, shows the V0 and a brief description of the palace. (**Scene 1**)

- Introduction, a checklist of actions to take to reach and visit the palace safely and independently. (**Scene 2** and **Scene 2a**)
- Paths, allows you to view rooms via 360 images and audio descriptions and text. (**Scene 3** and **Scene 3a**)
- Rules, shows the rules to be followed inside the museum. Each rule written in text formats is associated with an infographic via a popup. (**Scene 4**)

1. Loading

The following use case is realized in Unity's Before scene. The goal is to download files at application startup related to museum management. Upon application startup, the IT_handling file, which contains all management-related data, is downloaded via the HTTP protocol. The C.3 script allows precisely to initially download the IT_handling file and then to download all resources from Google Drive. The script is placed on the DownloadServer object This object is not destroyed on transition to the home page.This is done while a simple interface incorporating the application logo and the loading sign.

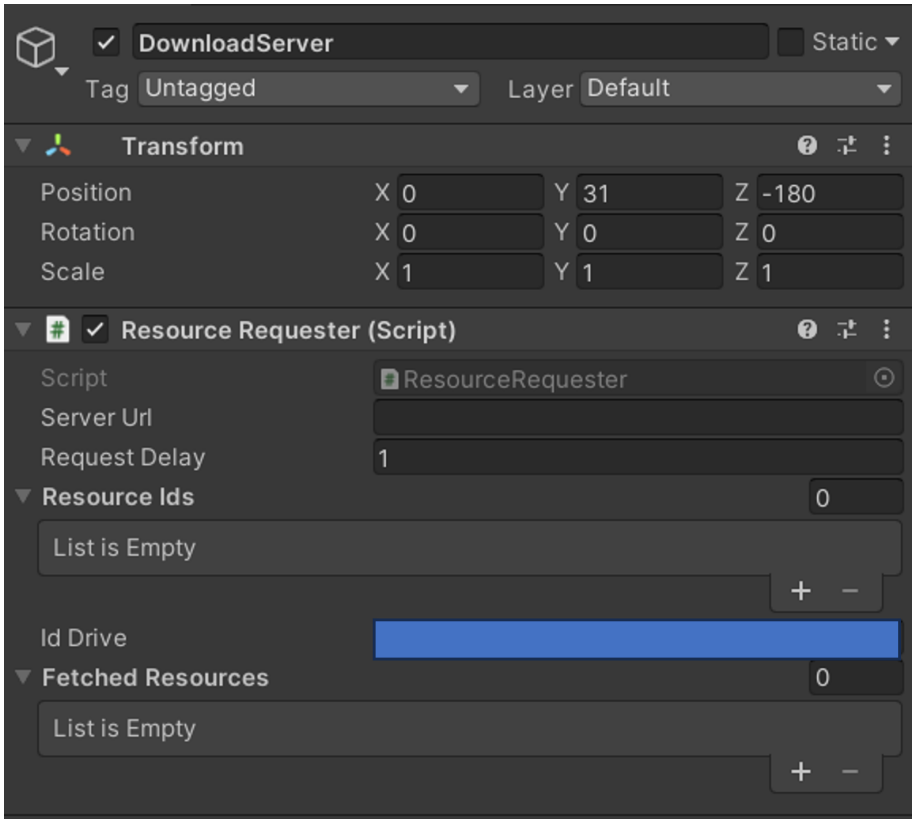


Figure 4.33: Inspector that shows all the components of the DownloadServer object.

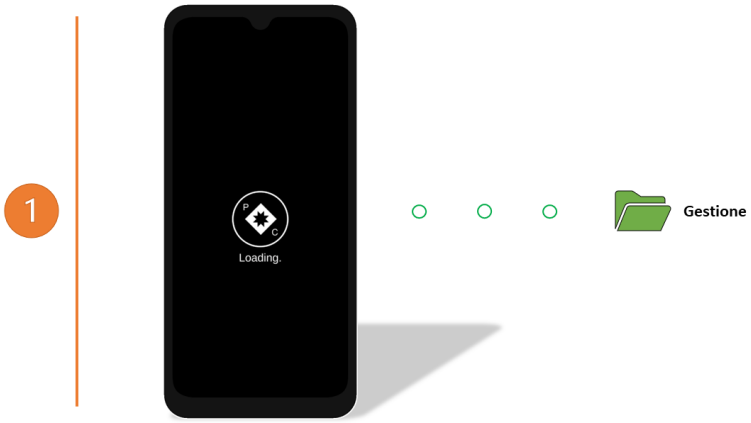


Figure 4.34: App Mockup - Loading Interface

2. Home

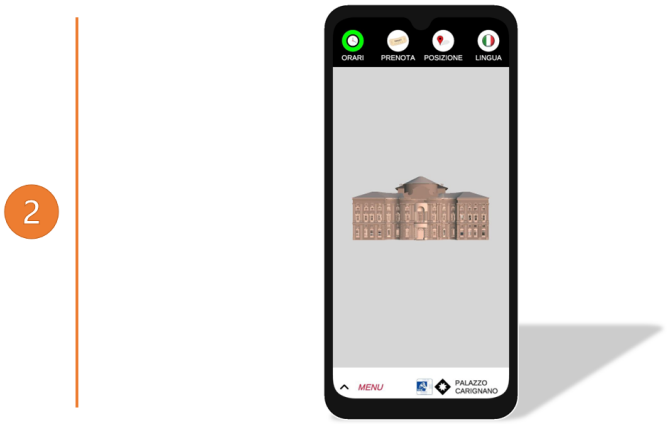


Figure 4.35: App Mockup - Home Interface

The home page displays the BIM model with its animation. This shows how to rotate and zoom the model. The C.4 script takes as input the touch data of the device being used and based on this rotates or zooms the model.

On the black panel in other it is possible to access all the management services of the museum. The management services of the museum are:

- TimeTable
- Ticket
- Position
- Language

Figure 4.36: App Mockup - Home Interface. Shows the animation created to indicate how to rotate and enlarge the model.

While at the bottom is a drop-down menu that allows the user to view the historical contents of the museum. In this case the exposed features are:

- Palazzo Carignano
- Introduction
- Path
- Rules

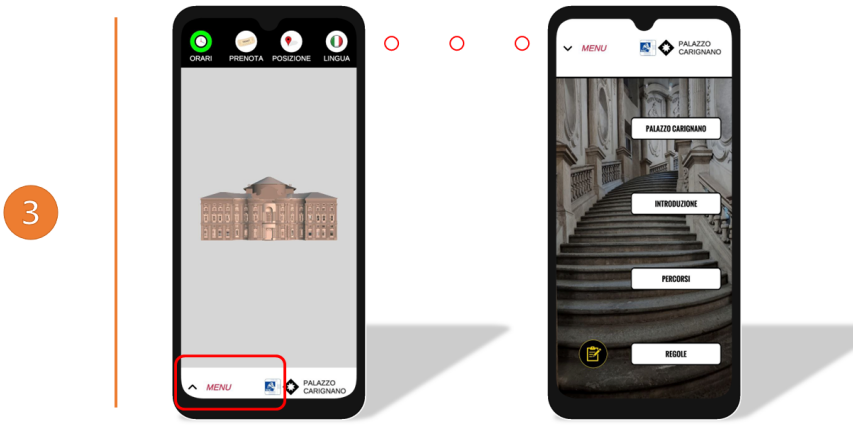


Figure 4.37: App Mockup - Home Interface. Shows what happens when the user clicks on the arrow to access the menu.

The timetable icon changes color based on the opening and closing of the museum. The colors are uniquely chosen. Red is chosen for closing, while green is chosen for opening.

2.1 - Language

The language pop-up allows the entire application to be set to the desired language. When the user clicks on the chosen language all videos are downloaded from Google Drive via script C.5.

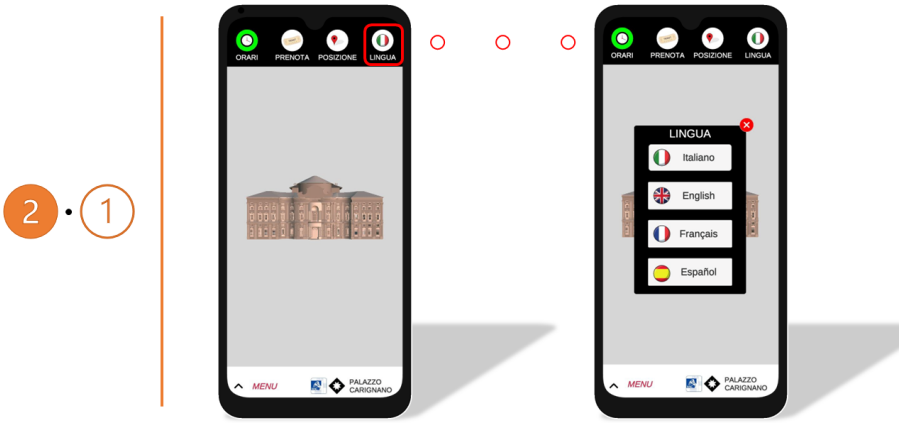


Figure 4.38: App Mockup - Language pop-up.

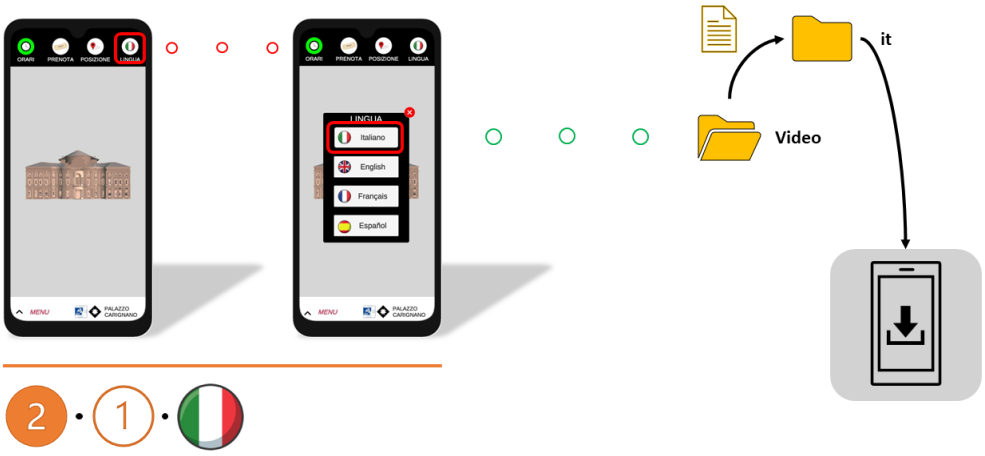


Figure 4.39: App Mockup - Language pop-up. When the user selects the Italian language all the corresponding videos are downloaded. Similarly, it occurs when the user selects another language.

2.2 - TimePanel

The pop-up of timetable shows all days of the week colored red when the museum is closed and green when open, respectively. In addition, for days when the museum is open, the opening and closing times are shown. ARAASAC symbols are associated with these. All data are taken from the DownloadServer object.

(a) (b)

Figure 4.40: (4.40a) ARASAAC closing symbol; (4.40b) ARASAAC opening symbol.

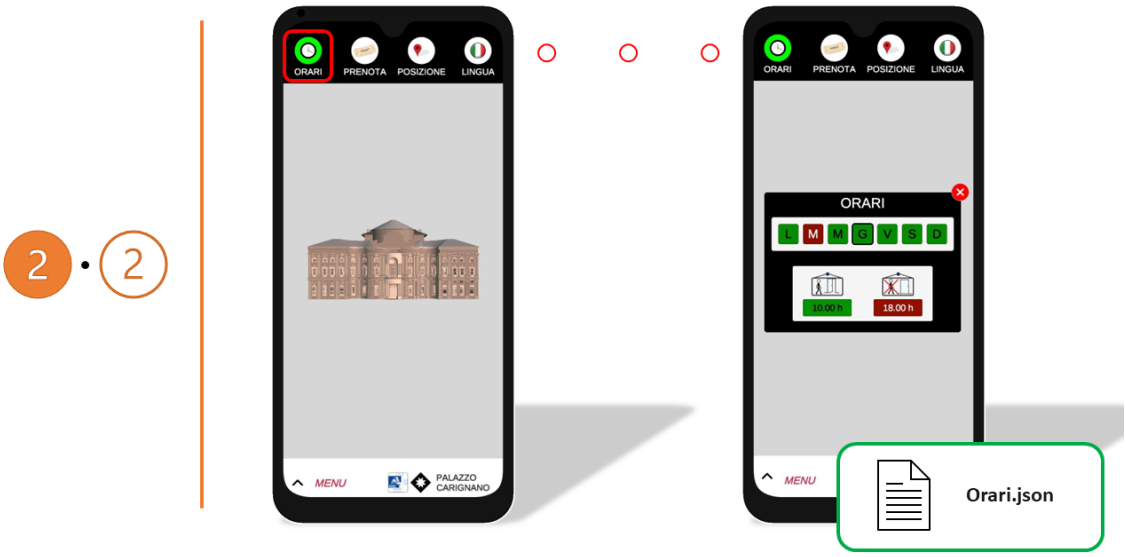


Figure 4.41: App Mockup - TimePanel Interface.

2.3 - Ticket

The following pop-up is intended to provide for all ticket-related needs. The data required to correctly fill out the pop-up ticket are:

- museum cell phone number;
- museum e-mail;

- url of the museum's web page;
- full ticket price;
- reduced ticket price ;

For the first 3 points, above, each is associated with a button that allows the desired action to be reached.

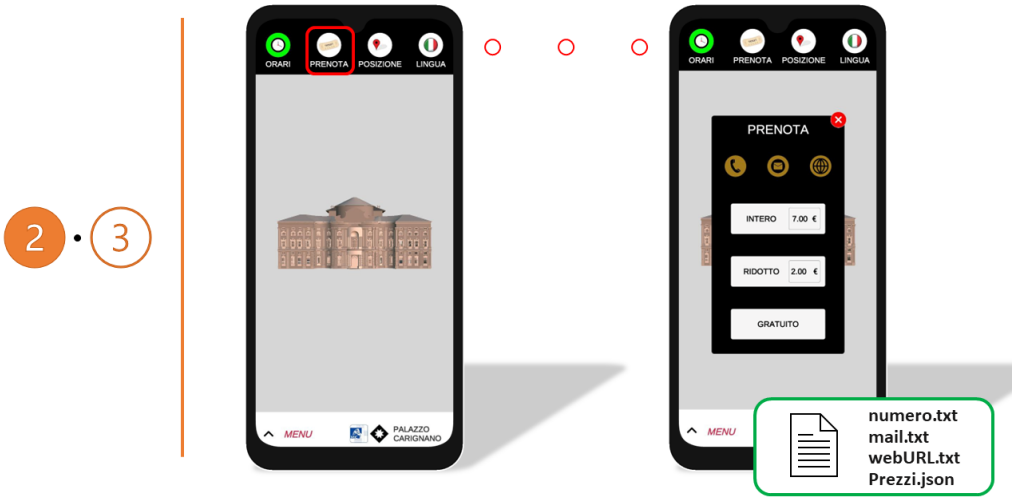


Figure 4.42: App Mockup - Ticket Interface.

2.4 - Position

When the user selects the location button this is redirected to the Google Drive web page of Palazzo Carignano.

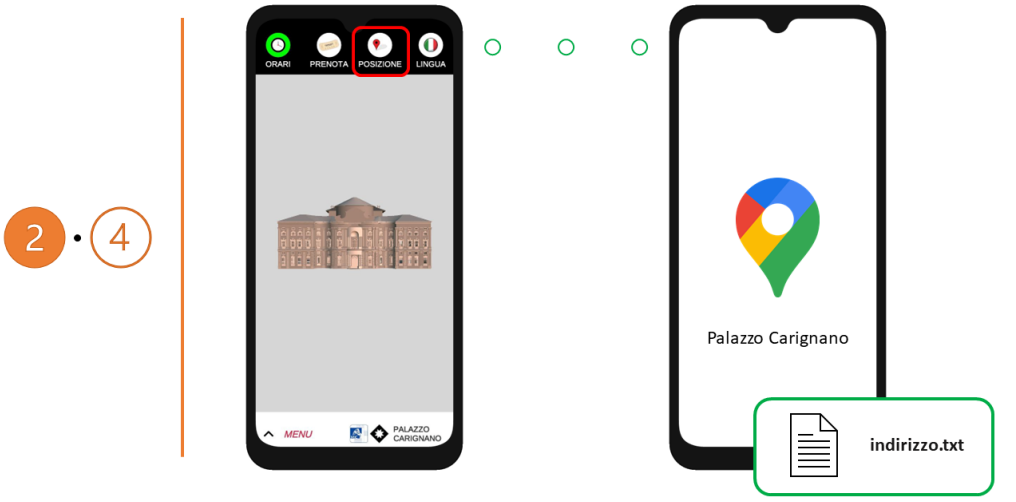


Figure 4.43: App Mockup - Position Interface.

3.1 - Palazzo Carignano

The Palazzo Carignano feature aims to show through a video, V0, and a text description what is inside the museum. The text description is taken from Google Drive via HTTP protocol. The script C.7 in Unity is used for all video management.

Figure 4.44: App Mockup - Palazzo Carignano Interface.

This allows for the following:

1. **Time controllers** allow for advancing or retracting the video by 5 seconds.
2. **Play/Pause button** allow for stopping or playing the video.
3. **Speed controllers** allow for increasing or decreasing the speed of the video.
4. **Enlarge/Reduce button** allows displaying the video in full screen or reduced.
5. **Time bar** allows displaying the time of the running video.

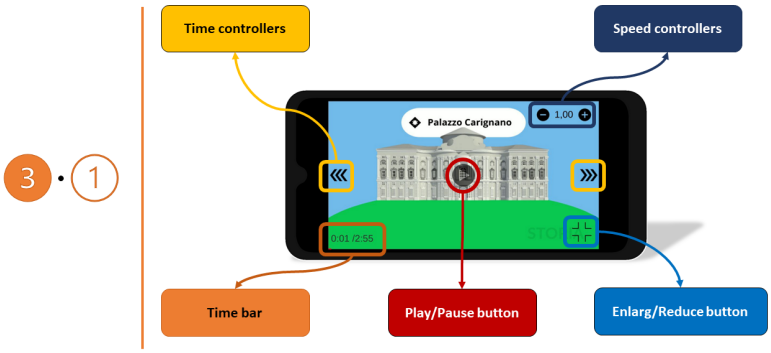


Figure 4.45: Video preview, which shows all the components that a user can use during video playback.

3.2 - Introduction

Before detailing this feature, it is necessary to describe what causes its design. The function is designed to provide a checklist that guides the user through the following steps:

1. Reaching Palazzo Carignano.
2. Admiring the facade of the Palace.
3. Reaching the entrance.
4. Buying the ticket.
5. Requiring a ticket map.
6. Beginning the tour.

Associated with these are videos V1, V2, V3, V4, V5, V6, V7, and V8.

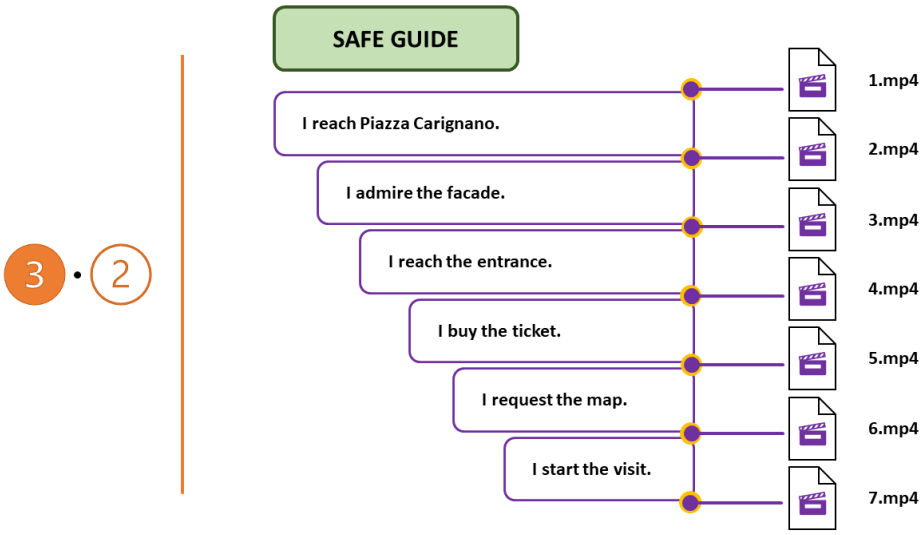


Figure 4.46: Summary of the guidebook to be used to visit the museum with accompanying videos.

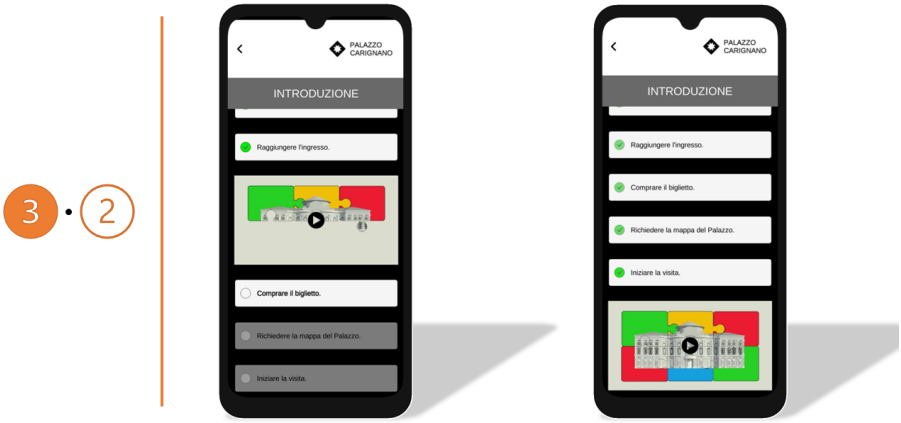


Figure 4.47: App Mock up - Introduction Interface.

8 - AAC Introduction

The following feature is the same in terms of content as the previous one; however, the latter is provided differently. The text has been replaced with symbols from ARASAAC. Upon selection of these, a request is sent to Google Translator to receive audio input.

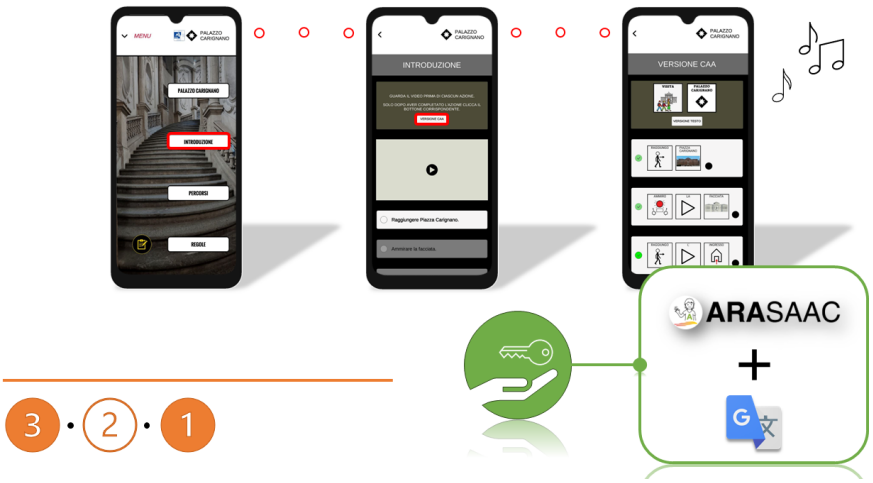


Figure 4.48: App Mock up - AAC Introduction Interface.

3.3 - Path

The paths section aims to create a digital tool that makes people fully understand what is inside the museum. three paths can be selected within the paths section.

1. Midday Apartment
2. Staircase
3. Midnight Apartment

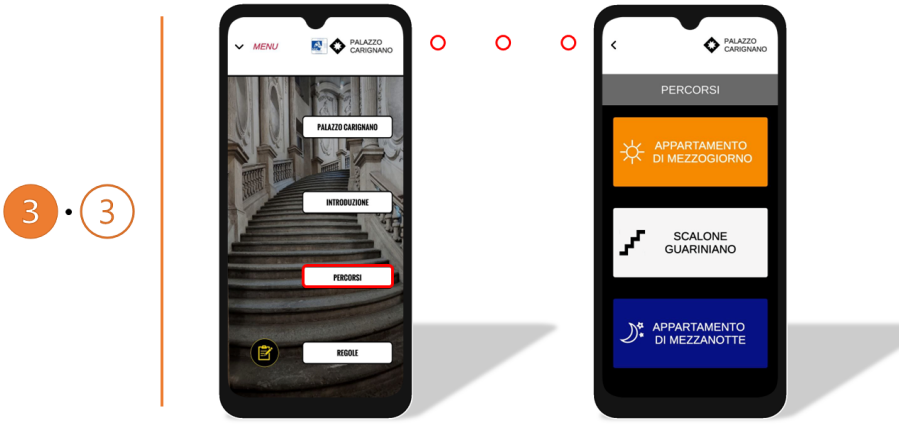


Figure 4.49: App Mockup - Path Interface. The user can select the route they want to visit.

A class is created for each room belonging to each pathway to make the system scalable. The class shown in script C.6 characterizes each of the appropriations with the following parameters:

- **Name** - indicates room's name;
- **Path** - indicates path's name;
- **ImageButton** - the image of the associated unselected button;
- **ImageHButton** - the image of the associated selected button.
- **Plant** - the image of plant;
- **Material** - the 360° image of room;
- **Description** - indicates the text description or ID file associated;
- **Button** - Game Object of button associated;
- **status** - boolean indicating whether the room is selected.

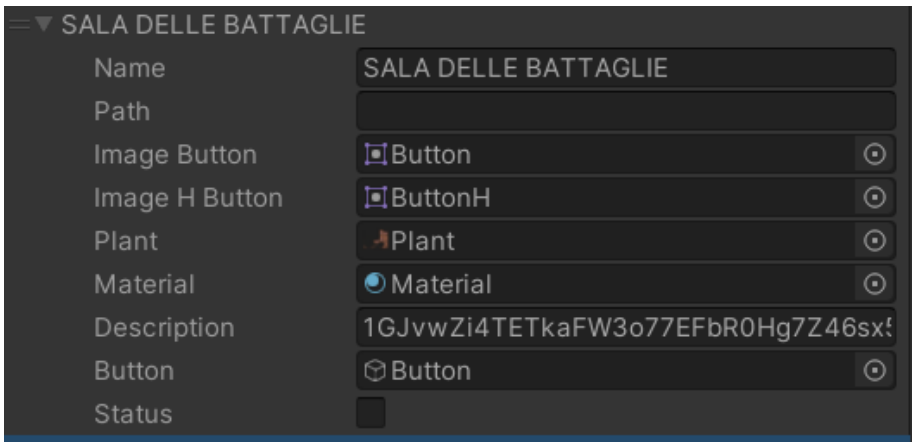


Figure 4.50: Example of a room class within Unity's inspector

Each path, on the other hand, is managed by the ManagePath script that allows you to add the number of rooms, set parameters for each room. In addition, this allows for an audio file using the free Google translator API. Given the character limitations of the latter, a subdivision of the text into subsections is necessary, paying attention to punctuation.

Figure 4.51: App Mockup - Path Interface. Example of an interactive map.

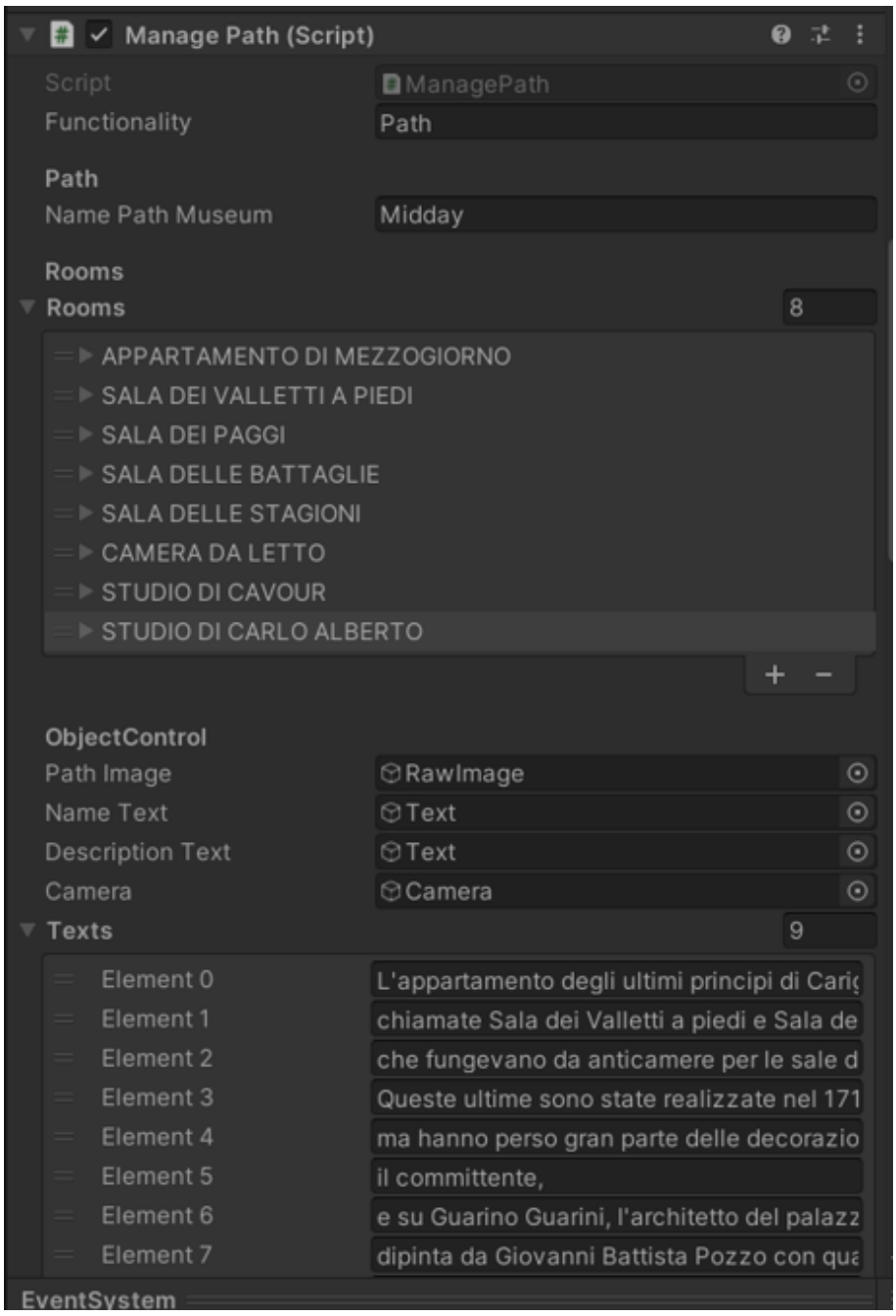


Figure 4.52: Example of a ManagePath within Unity's inspector.

Figure 4.53: 360° image showing the hallway of Palazzo Carignano.

3.4 - Rules

This feature is intended to describe what the rules within the museum are uniquely. The interface shows the rules, and by selecting on each rule, a pop-up appears that invokes it.

(a) **(b)** **(c)**

(d) **(e)** **(f)**

Figure 4.54: (4.54a) Turn off the mobile phone ringer; (4.54b) Do not eat; (4.54c) Do not run; (4.54d) Do not use the flash;(4.54e) Do not touch the artworks and wall; (4.54f) Do not use shout.

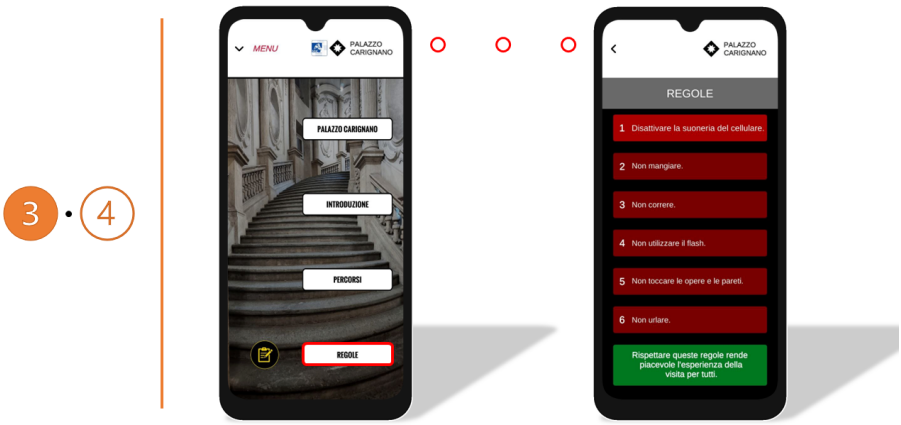


Figure 4.55: App Mockup - Rules Interface.

11 - GoogleForm

When the user selects the location button this is redirected to the Google Form web page. The form presents a questionnaire with the objective of collecting data on experience with the application.

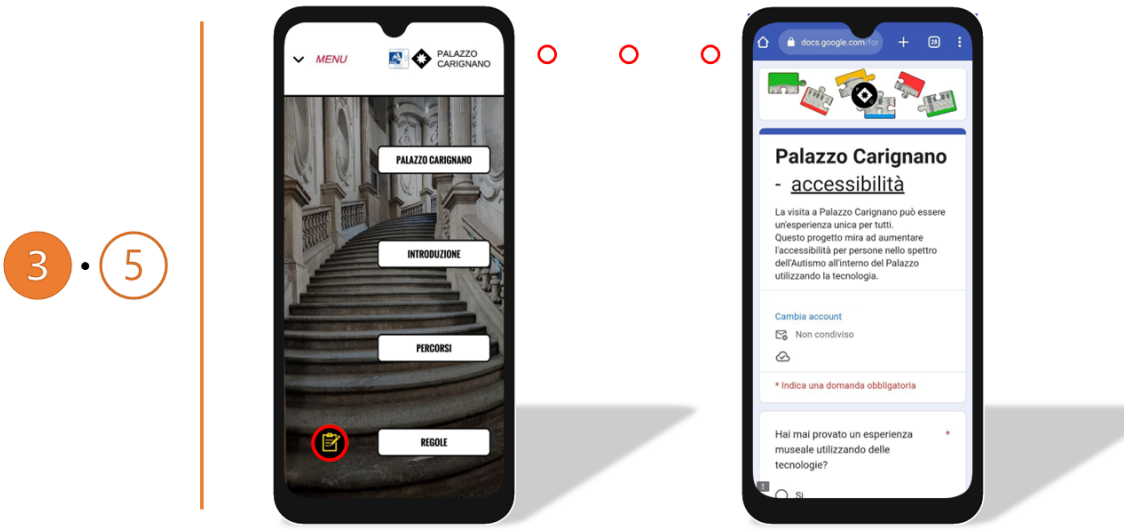


Figure 4.56: App Mockup - Google Form Interface.

4.7.4 Platforms

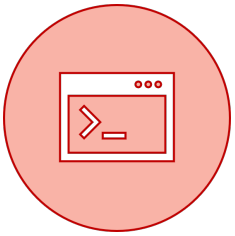
The application is designed for Android devices, version no lower than 5.0, but not for IoS devices, however this step should not be problematic.

Figure 4.57: Minimum Android API setting.

4.7.5 Guides for all actors

In addition to providing the service of the mobile application, there are also two guides that allow greater accessibility to the system. Guide A is designed for practitioners working within Palazzo Carignano, this one shows how to be able to edit descriptions within the Google Drive so that experts can be left with their own communication strategy. The release of the Drive is the key to all-around accessibility. While Guide B, "Guide for All", written in Italian with the AAC aims to illustrate how to use the application step by step, detailing each step. Finally, the Guide C for IT staff section is a collection of meaningful scripts for implementing the services developed, from the mobile application to those that follow.

4.8 Augmented Reality Experience



AR has much potential both in the museum context and for users on the ASD. Starting from the definition of AR that adds information to reality, this can be used, for example, to have content in AAC when artwork or a particular object is framed with a cell phone. In this section, its potential applications in the museum context will be discussed, and a low-level prototype will be proposed, analyzing what frameworks allow the realization of these in Unity.

Starting from what may be the causes that lead a visitor with ASD to be in situations of over stimulation and consequent unsafe for himself, solutions with AR are proposed in following table.

Situation of over stimulation	**AR Solution**
1. Lack of indications or poorly visible indications	AR guide
2. Lighting too strong	Frame analysis to identify illumination greater than a threshold
3. Sound too strong	Audio analysis to identify sound greater than a threshold
4. Unreadable descriptions	Descriptions in AAC

Table 4.5: Identification of situations where AR is used to inform the user to take cautions or directly help the user.

4.8.1 Framework for Augmented Reality in Unity

The production of AR experiences for several platforms, including iOS and Android, is made easier with the help of the potent AR Foundation framework for Unity developers. The ARKit (for iOS) and ARCore (for Android) native AR technologies offered by Apple and Google are connected by this framework to Unity's cross-platform development capabilities [125].

Relevant features provided are:

- **AR Session**. By enabling or disabling augmented reality on the target system, the ARSession component manages the entire life cycle of an AR experience.
- **Device tracking** uses the XROrigin component to automatically manage device tracking and object change for tracked objects in Unity's coordinate system.
- **2D Image tracking** throughs the supervised image manager, every image in the environment is converted into a GameObject. It is crucial to advise the manager to look for a collection of reference images that have been put together into a reference image library before detecting an image. The manager is only able to detect photos that are present in this library [126].

Unity's AR Foundation
Supported Features

Functionality	ARCore	ARKit	Magic Leap	HoloLens
Device tracking	✓	✓	✓	✓
Plane tracking	✓	✓	✓	
Point clouds	✓	✓		
Anchors	✓	✓	✓	✓
Light estimation	✓	✓		
Environment probes	✓	✓		
Face tracking	✓	✓		
Meshing			✓	✓
2D Image tracking	✓	✓		
Raycast	✓	✓	✓	
Pass-through video	✓	✓		
Session management	✓	✓	✓	✓

Figure 4.58: Unity's AR Foundation supported features [127].

4.8.2 Image Tracking

Using AR Foundation's extensibility propriety, it is possible to customize all the types of features it offers. C.8 script allows one-to-one correspondence between tracked image and corresponding prefab. The prefab can be of any type from a panel containing information to a 3D object. The library of reference images are shown below. Although the prototype shown is low-level, it has great potential, because referring to the definition of AR as a technology that interposes itself between real space and virtual space, the content that is proposed can be of any kind. Not only a model with the mere intent of visualisation as shown in the picture but it can be informative. Furthermore, within the app vie given the possibility of applying a colour filter to images taken from the mobile phone, simulating and recreating a virtual sensory bag. With the aim in the case of over-stimulation due to intense colours, strong light to mitigate this situation.

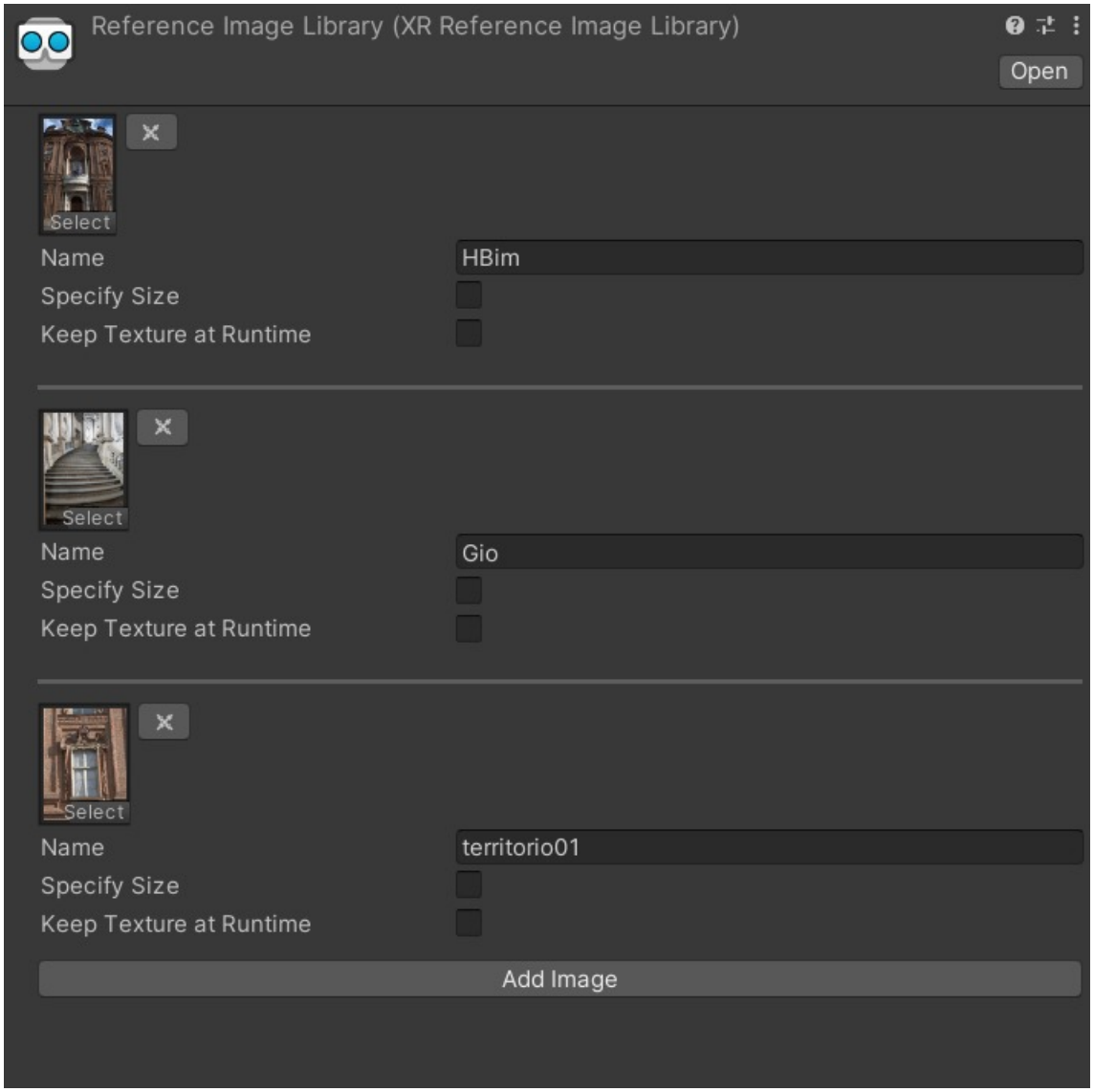
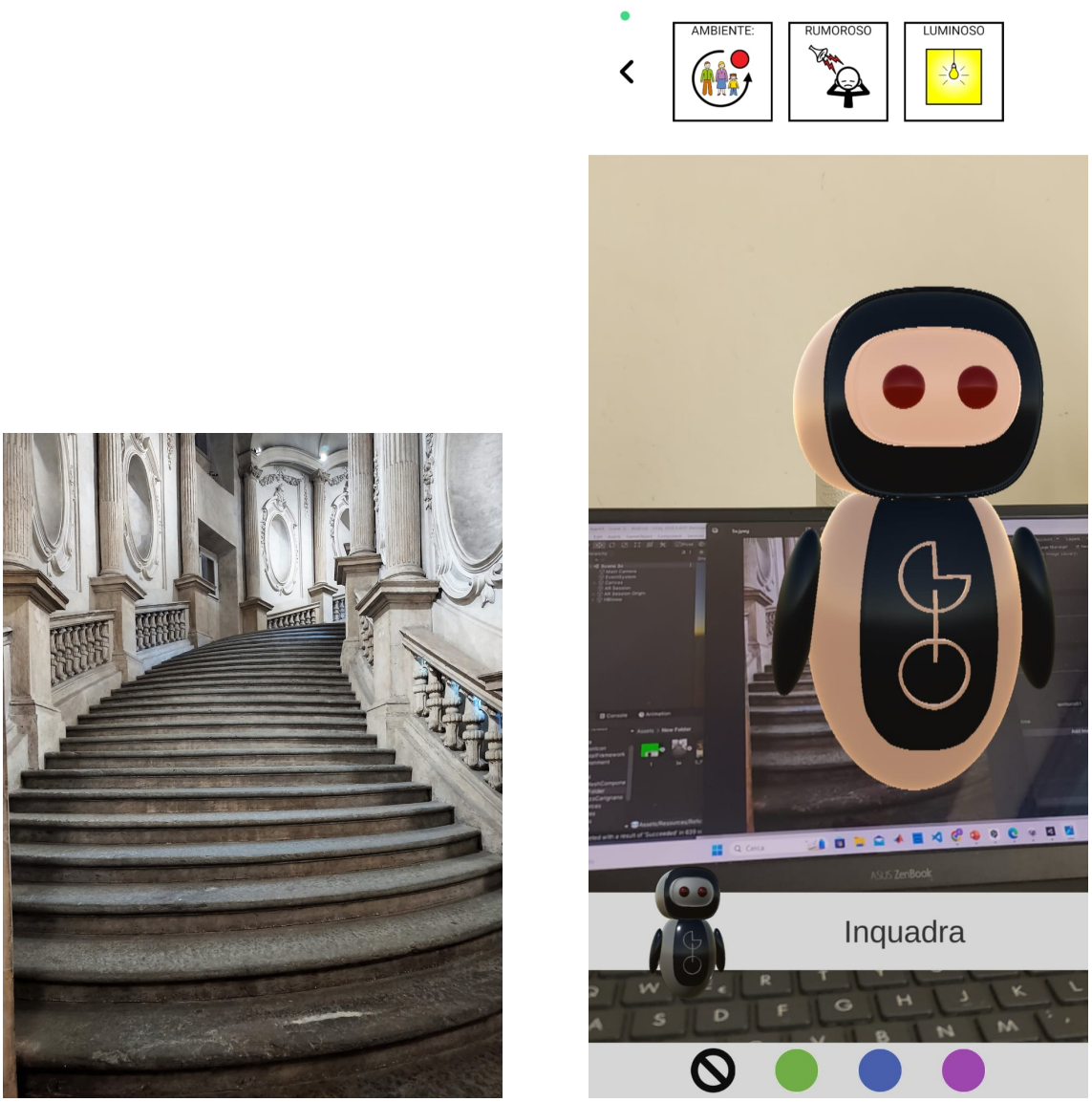


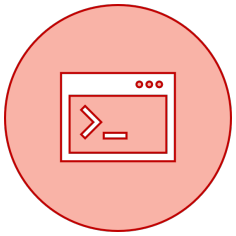
Figure 4.59: Screenshot of the reference image library object within the Unity inspector.



(a) **(b)**

Figure 4.60: (4.60a) Tracked image; (4.60b) Screenshot of the AR app when the image on the left is drawn.

4.9 Virtual Reality Experience



There is a thoughtful discussion on the benefits of VR technology in the fields of education and rehabilitation for various clinical groups [128, 129, 130]. But VR unlike AR does not come between the user and reality. Therefore, the design of the virtual environment must be designed appropriately to try not to overstimulate the user. The objective of the VR experience is to create a situation in which the user can walk around the surroundings of the museum and reach it. Once this is reached, he or she can admire the structure of the building. The user is accompanied by an avatar, Gio, who can assume various functions. The following subchapters will describe the devices that were used, the framwork required for the implementation of this experience in Unity, the design of the user, the environment and the suppository avatar.

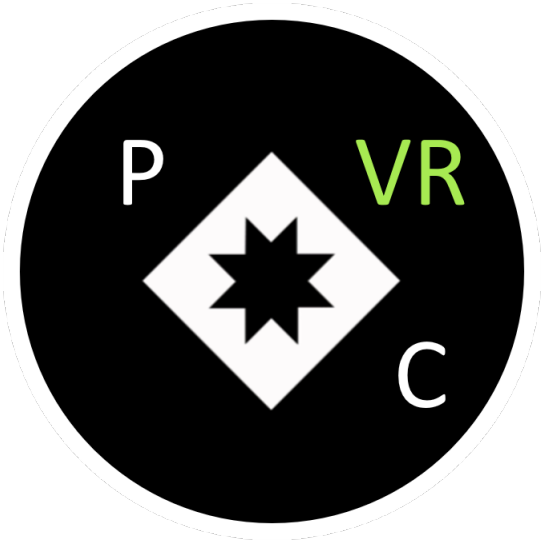


Figure 4.61: VR app logo. The museum logo is used for logo and in addition the diagonally placed initial is also used.

4.9.1 Hardware for Virtual Reality

The following devices are used for the project:

- **SteamVR Base Stations 2.0** reaching out to around 5 meters, the laser lines and several sync pulses sweep the room. For any positionally tracked equipment, including the HMDs and controllers, they act as reference points. The laser-based tracking system is the Lighthouse. Lighthouse was created by Valve for SteamVR and the HTC Vive. Each base station has two fast spinning laser emitters as well as the IR beacon known as the Sync Blinker. While one of the lasers sweeps a beam across the room, the Sync Blinker fires synchronization pulses 60 times per second. Controllers and HMD receivers pick up on both the laser beam and the synchronization pulse. The receiver calculates the laser beam's precise position by measuring the interval between the synchronization pulse and the laser beam's arrival. When two base stations are used, the position and orientation in the room's 3D space are established [131, 132].

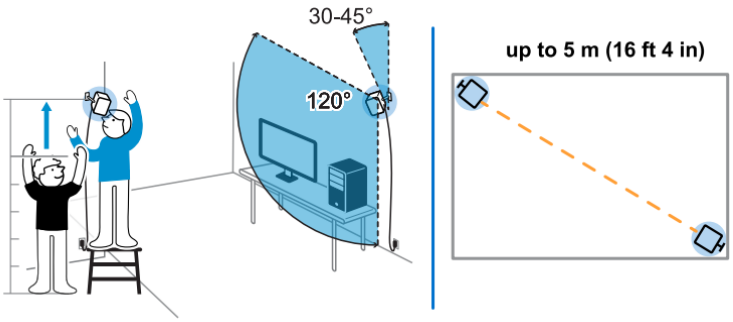


Figure 4.62: SteamVR 2.0 base station manufacturers' recommended configuration [133].

- **HTC Vive Pro 2 HMD** allows scenarios to be viewed in VR using its lenses. The specifications are shown in Table 1.1. The device is chosen over its competitors because it presents better results in terms of graphics resolution.

Figure 4.63: HTC Vive Pro 2 HMD [134].

- **2 HTC Vive Pro 2 controllers.** With 24 sensors, a multi-purpose trackpad, a dual-stage trigger, HD haptic feedback, and a rechargeable battery. The HTC VIVE Pro Controller enables wireless interaction with the virtual world.

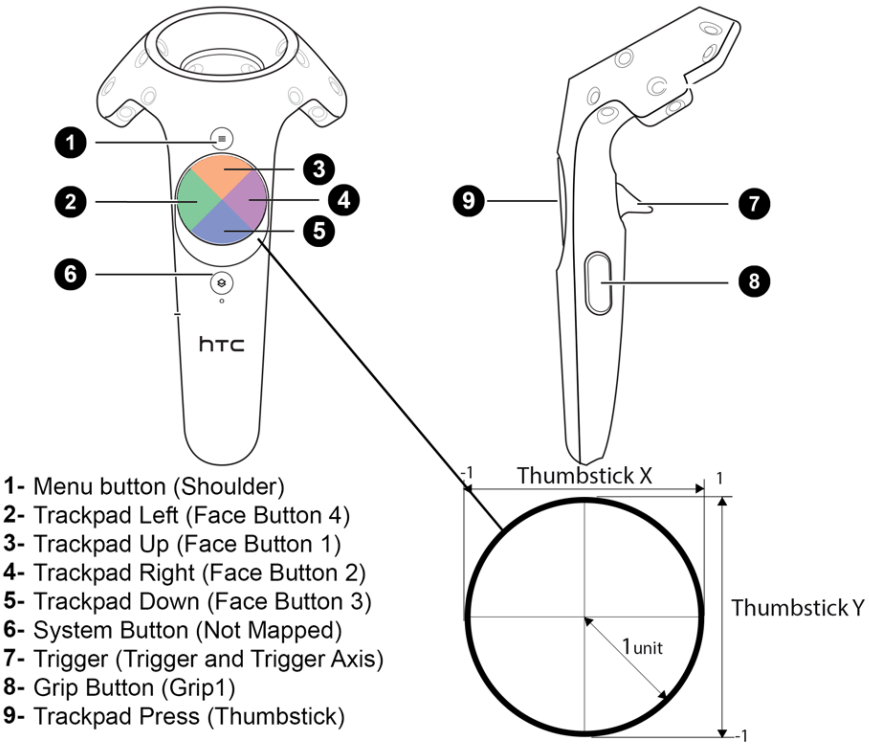


Figure 4.64: HTC Vive Pro 2 controllers and their configuration[135].

- **Vive Tracker**, a device that allows to track the location and orientation of any object in VR. It can be paired with other devices that ensure correct usage or proper ergonomics. For example, in the present case it is used with waist and wrist straps.

Figure 4.65: Vive Tracker device [134].

All of the above-described controllers use Inertial Measurement Units (IMUs) technology, which is widely used in the context of biomedical engineering, for example,

to evaluate gait analysis. The gait is considered as the sixth vital parameter [136]. However, in these applications it is necessary to evaluate the precision and accuracy of the acquired measurements.

4.9.2 Framework for Virtual Reality in Unity

Valve Software developed the SteamVR Unity plugin, or just SteamVR, in 2015 [137]. The same business that introduced VR headsets like the Vive and Index is also known for creating Steam, the well-known PC game distribution platform.

User

The player prefabrication provided by SteamVR is used for user realisation. The prefab allows the visualisation of the virtual environment via the HMD and to interact through the controllers with virtual objects.

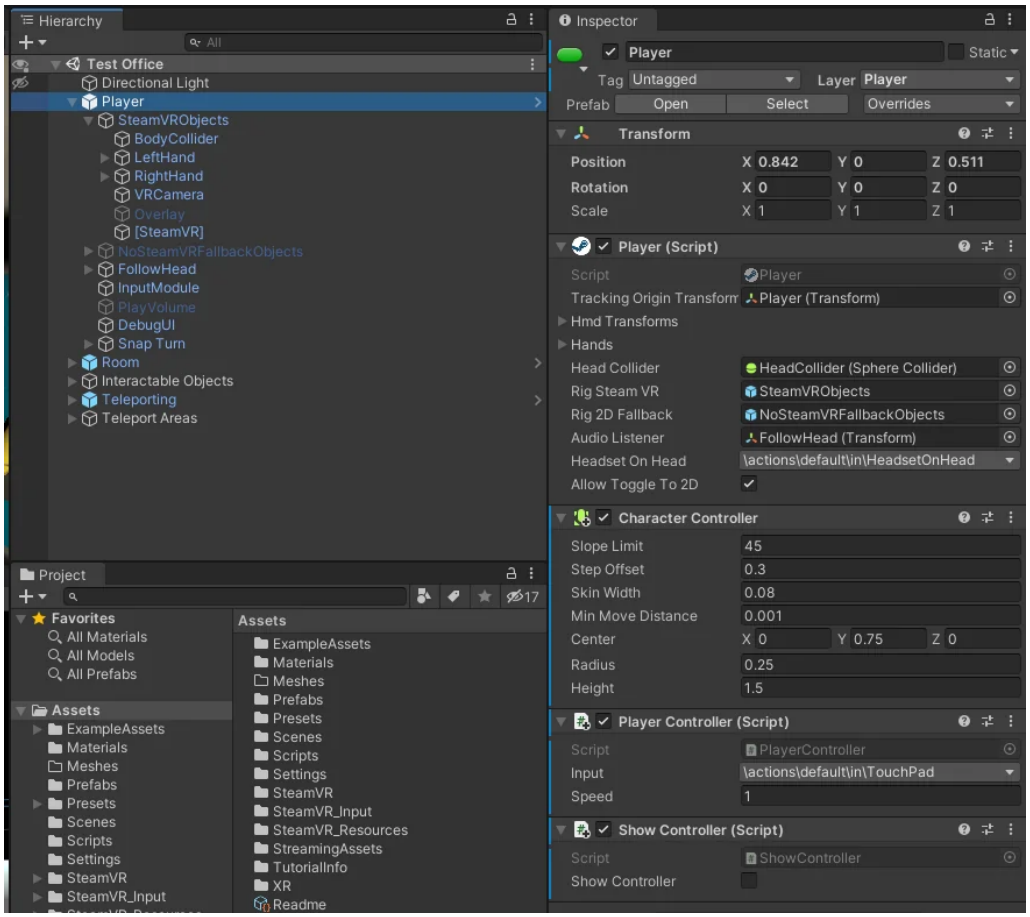


Figure 4.66: Screenshot of the hierarchy and inspector of Unity where the prefabricated SteamVR Player is shown.

The GameObject VRCamera child represents the HMD, while the LeftHand and RightHand children correspond to the two controllers.

4.9.3 Virtual Environment

The same procedure as in Chapter 4.4 is used to construct the virtual environment. In addition to the BIM model of the building, the model of the areas surrounding the museum is also imported in order to contextualise the experience.

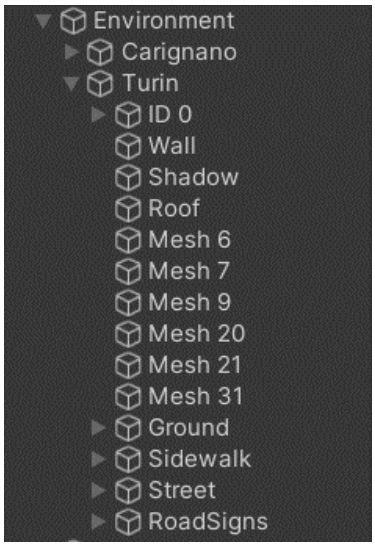


Figure 4.67: Screenshot of the environment object within the Unity inspector. This consists of the Carignano object representing the BIM model in gLTF format and Turin with all its children with their labels.

The area surrounding the museum is characterised by meshes divided according to their function in reality; e.g. roof, road, wall, etc. Each of these is manually associated with the TeleportArea script which allows or disallows the user to teleport to the corresponding area. The TeleportArea script is provided by SteamVR plugin. Teleportation is only made possible on the sidewalk Child of Turin GameObject.

Figure 4.68: Virtual environment perspective number 1.

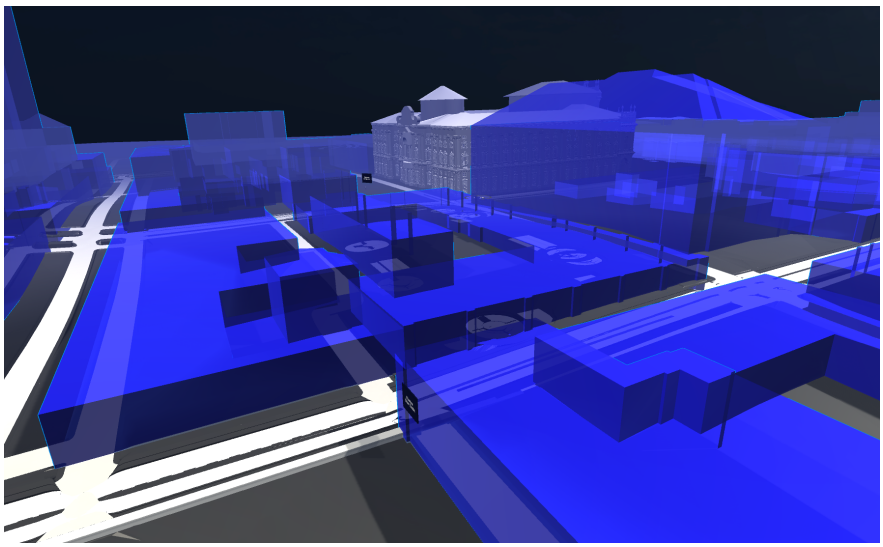


Figure 4.69: Virtual environment perspective number 2.

4.9.4 Avatar

One of the main problems of museum VR applications is the lack of interaction with other users [138]. To compensate for this lack, an avatar is created to follow the user from the outside. The functions of the avatar can be mainly two:

1. the caregiver wearing devices as well as the user with autism could make him/her feel comfortable.

2. the museum guide can wear the devices in order to guide the user and provide all the necessary details.

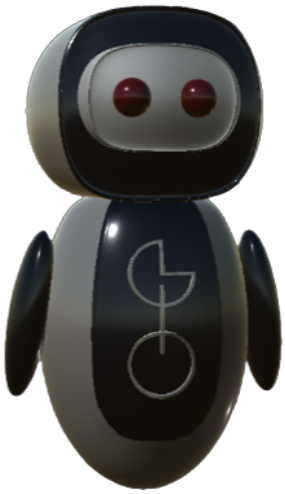


Figure 4.70: Model of the avatar used as a user within the virtual reality experience.

To bring the avatar model back into VR, 3 Vive Trackers are used. The positioning set-up is as follows:

- Vive Trackers no. 1 is strapped on the pelvis;
- Vive Trackers no. 2 is placed at 2 cm of the right elbow;
- Vive Trackers no. 3 is placed at 2 cm of the left elbow.

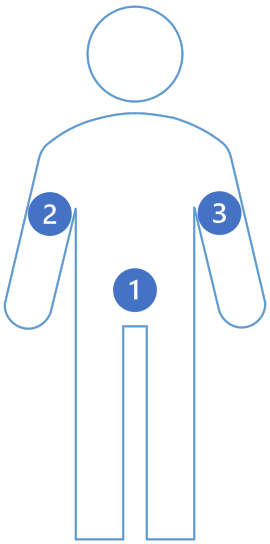


Figure 4.71: Model of the avatar used as a user within the virtual reality experience.

The avatar model is imported into Unity in gLTF format.

Figure 4.72: Screenshot of the GameObject within the Unity inspector that represents avatar Gio.

To track the orientation and position of the body the GameObject is associated

with the class *SteamVR_TrackedObject*. All children of the GameObject are associated with a Collider. Two classes *HandScript* and *HandScriptTest* similar to *SteamVR_TrackedObject* are created, which in addition to tracking position evaluate collisions between the avatar's arms and body. Class *HandScriptTest* verifies that there has been a collision, while class *HandScript* keeps track of the position so that it renders properly. GameObjects Spere, Sphere(1), Sphere(2) and Sphere(3) simulate the glenohumeral joint. At the GameObjects Spere, Sphere(1) are attached class *HandScriptTest*, while at the other two are attached *HandScript*.

Chapter 5

Results and discussion

This chapter comprehensively elucidates the multiple phases of testing currently taking place within each project, providing a detailed account of the results continually emerging throughout the ongoing research activity. The participants actively engaged in these testing phases include a diverse group of individuals, encompassing seasoned professionals with expertise in the field and general users who are actively utilizing the applications under audit. It should be stressed that all the stages described above from empathizing with end users to the prototyping stage were shown in a linear manner; however, this was not confirming the non linearity of the method itself.

5.0.1 Meeting of December 5, 2022

During the meeting at 7 p.m, the validation of actors is being conducted, which includes professionals and institutions such as the Direzione Regionale dei Musei, associations dedicated to autism (Centro Regionale Disturbi Spettro Autistico, ANGSA, and Cuori Blu). Only the videos and the VR application are being subjected to analysis. This evaluation, which is being conducted in VRLab, reveals several issues, including a lack of contrast in the videos, a high-speed presentation of the videos, ill-defined rules, and the necessity of delivering this service through appropriate platforms. An intriguing intervention is emerging, whereby the videos are being translated into the application, addressing concerns related to the videos' length, limited interactivity, and contextualization.

5.0.2 Meeting of May 17, 2023

At 7 p.m, in the VRLab, the meeting convenes with the presence of Rotary, Rotaract, and the specialized neurologist, Dr. Keller. The showcased services encompass the mobile app and the integration of contextualized and edited videos within the application. It is discerned from this meeting that the absence of audio in the videos might pose a potential issue. Critically, there are no comments regarding the contrast and speed of the videos, as they have been appropriately adjusted. However, in relation to the application itself, no need for redefinition is identified.

5.0.3 Meeting of May 29, 2023

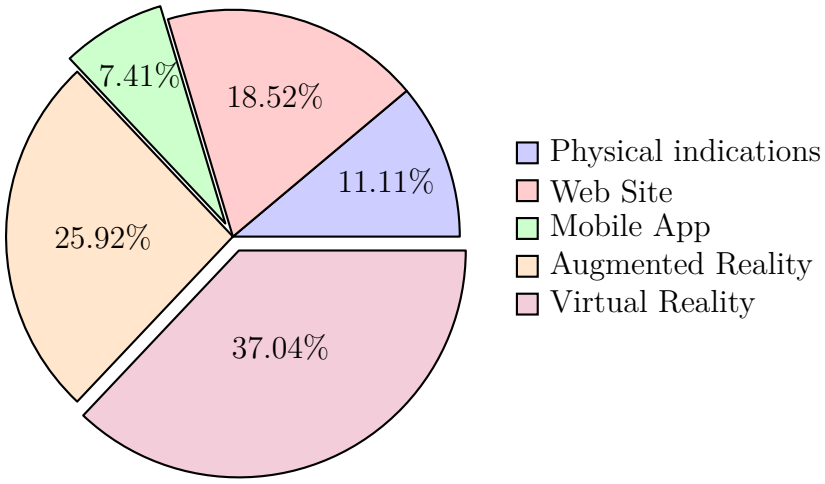
The only participant at this meeting, which is taking place inside Palazzo Carignano, is the Direzione Regionale dei Musei. The evaluation of the application's viability for prospective integration into the museum itself is the main topic on the agenda. Several important factors have come to light as a result of the meeting. First of all, it is highly relevant to include the knowledge of the museum's staff in the service. Second, the potential benefit of creating a multilingual application is becoming more accessible. For the former, the suggested option is to use Google Drive as a server to share the information, and for the latter, to start prototyping and implementing techniques aimed at making the application available in additional languages besides Italian, such as French, Spanish, and English.

5.1 Users feedback

There are 14 users in all who have tested the mobile app and/or VR experience. These are between the ages of 6 and 35. Users answer questions designed to analyse their use of technology within museums, how they rate in terms of accessibility of the virtual and mobile application in all its parts, how good the BIM is and finally whether the use of virtual reality can be used as a tool to increase people's quality of life. 50.0 % say they had never experienced a museum experience using technology, while the remainder indicated that the medium they used most was mobile applications. In addition, 1st question investigates which of these tools lead to a more accessible museum.

1st question

Which of the following tools enables the museum to be a more accessible space?



It is worth noting that with the first question investigating in terms of accessibility which means people think is most efficient, users report that virtual and augmented

reality are the means considered most efficient for more than 50 per cent of the applicants.

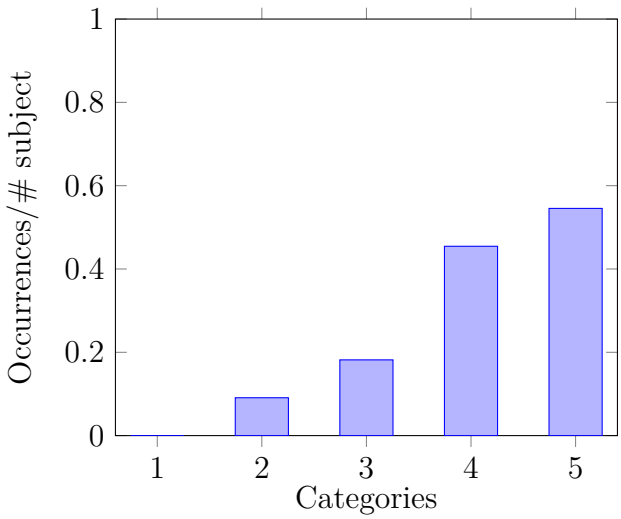
5.1.1 Building Information Model Resolution

The 2nd question seeks to understand whether users liked the resolution of BIM models. Users can respond using a scale, with 1 denoting total disagreement and 5 denoting absolute agreement.

2nd question

How did you like the resolution of the models?

(1: strongly disagree - 2: disagree - 3: neutral - 4: agree - 5: strongly agree)



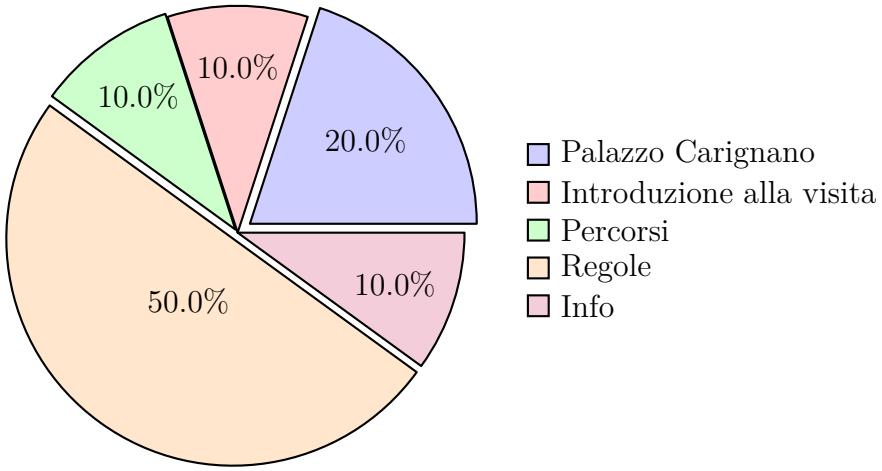
Average score BIM resolution: ★★★★☆ - 4.14/5.00

5.1.2 Mobile App

A total of 10 users have tested the mobile application. Each is asked which of the app's functionalities are least efficient, whether they have ever used AAC, and whether this tool is suitable in this context.

Mobile App. 1st question

Which of the features within the application did you find least effective?

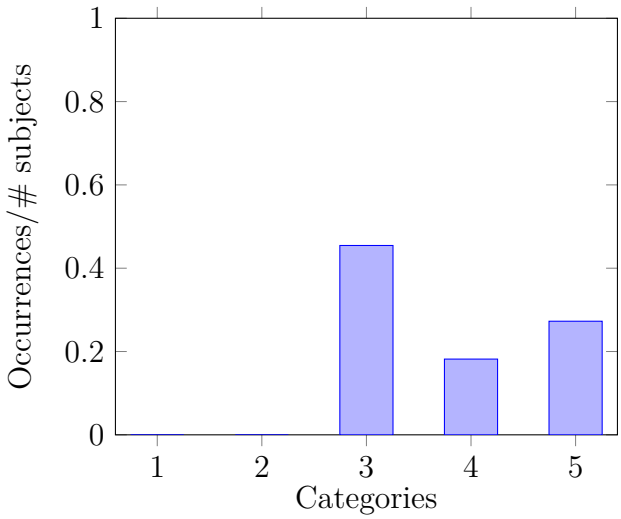


The following questions seek to investigate for each of the features exhibited by the application their how much they contribute to the accessibility of the museum. For each question the user can answer on a discrete scale with scores ranging from 1 indicating totally disagree to 5 totally agree.

Mobile App. 2nd question

Do you think the 'Palazzo Carignano' feature is efficient in terms of accessibility?

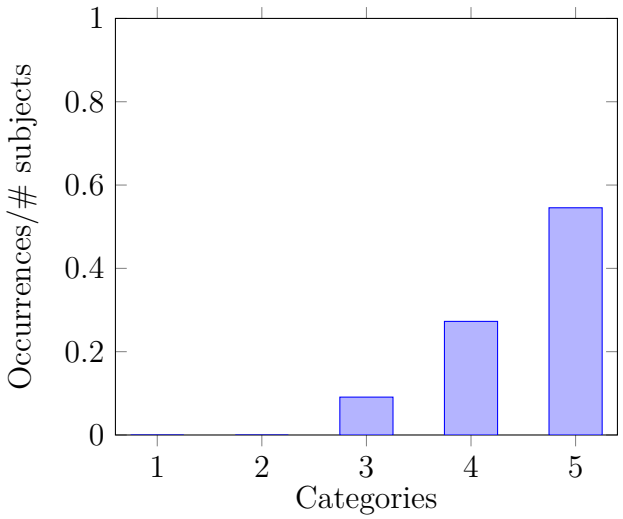
(1: strongly disagree - 2: disagree - 3: neutral - 4: agree - 5: strongly agree)



Mobile App. 3rd question

Do you think the 'Introduzione alla visita' feature is efficient in terms of accessibility?

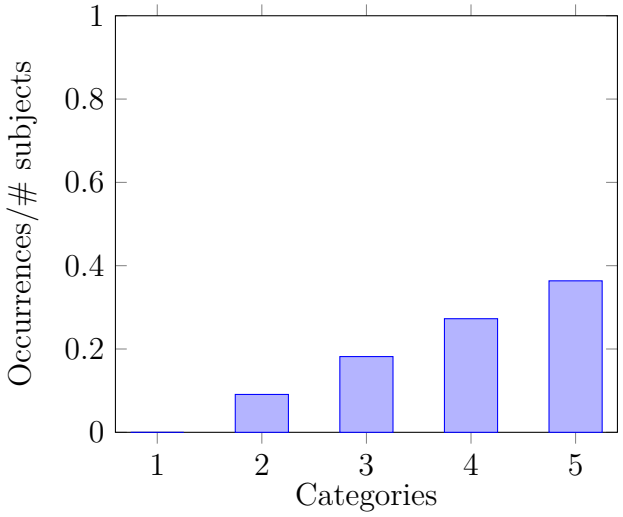
(1: strongly disagree - 2: disagree - 3: neutral - 4: agree - 5: strongly agree)



Mobile App. 4th question

Do you think the 'Percorsi' feature is efficient in terms of accessibility?

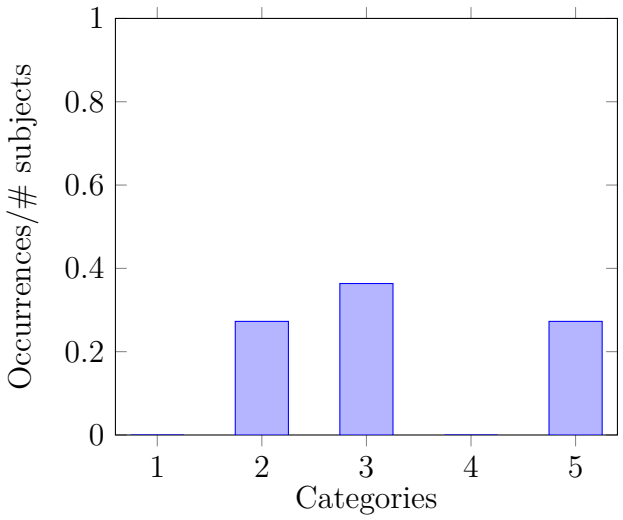
(1: strongly disagree - 2: disagree - 3: neutral - 4: agree - 5: strongly agree)



Mobile App. 5th question

Do you think the 'Regole' feature is efficient in terms of accessibility?

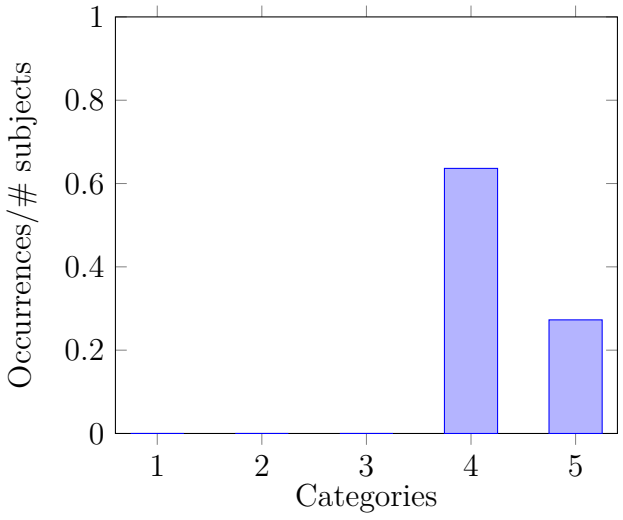
(1: strongly disagree - 2: disagree - 3: neutral - 4: agree - 5: strongly agree)



Mobile App. 6th question

Do you think the 'Info' feature is efficient in terms of accessibility?

(1: strongly disagree - 2: disagree - 3: neutral - 4: agree - 5: strongly agree)



Summarizing, the feature that users find to be most efficient is Introduction (average score equals to 4.5), while the 2 least are Palazzo Carignano and Rules confirmed both by comparing average rates (both with average score equals to 3.8) but also with the 1st question. Finally, 80 percent of individuals report that they have never used AAC, and that it fully fits the project in question.

Features	Average score
Palazzo Carignano	★★★★☆ 3.8/5.0
Introduction	★★★★½ 4.5/5.0
Path	★★★★☆ 4.0/5.0
Rules	★★★★☆ 3.8/5.0
Info	★★★★½ 4.3/5.0

Table 5.1: Average accessibility scores collected from 10 subjects for each feature exposed by the app.

5.1.3 Virtual Reality Experience

In this case, for virtual reality experience the only element under analysis is the presence of the GIO avatar. Users are asked if this makes the experience more stimulating. All users confirmed that the presence of this makes the experience more stimulating but this is not preferable to a human avatar.

Chapter 6

Conclusion

The effort to make culture accessible must be a priority of all museums as directed by ICOM [15]. However, this process requires the involvement of multiple actors with different experiences. It cannot be supported by only one professional figure but multidisciplinary teams are the solution of the process itself [66]. The use of technological means is an alternative to traditional means, but these must be designed paying attention to the end users. However, making a service accessible to a specific user should not exclude others, but a fair compromise must be made to include everyone in the design. An alternative may be to design specific user experiences that are customizable to the user who will use them. As for the developed project this needs improvement regarding the two XR experiences, while for the mobile app it will be important to monitor users' feedback to make consistent changes. HBIM is an important solution for collecting and sharing historical cultural data, and through the shift from BIM-based software to non-BIM-based software it demonstrates its power. This shift is a challenge that must affect all disciplines, as every action in our lives happens in a place and being able to map this will be able to make people's lives better.

On a final note, the project can be seen as a potential, relevant contribution to my country, as it indeed identifies as the world's richest cultural heritage – which along with contemplation and touristic sourcing, surely needs digitization and accessibility to all.

Appendix A

Guide for Museum Staff

This guide aims to explain how museum staff can modify information within Google Drive in order to provide the most up-to-date information to users through the mobile app.

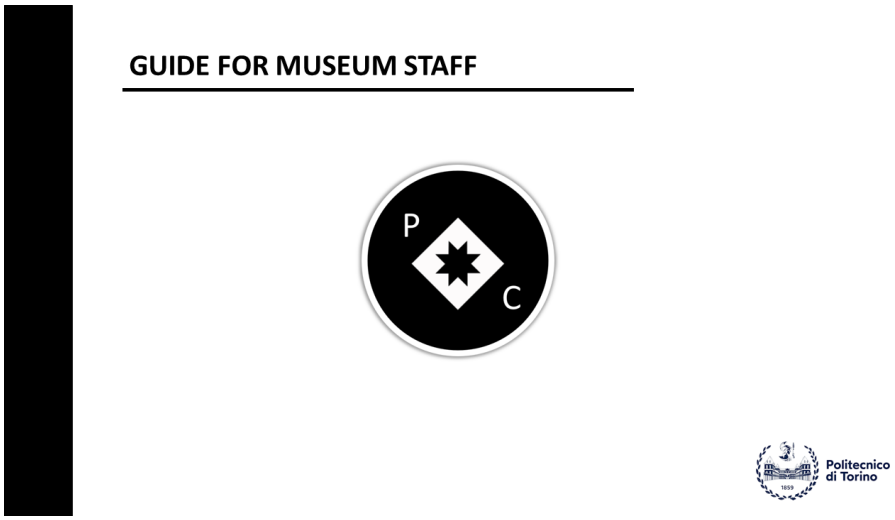


Figure A.1: Guide for Museum Staff, page 1.

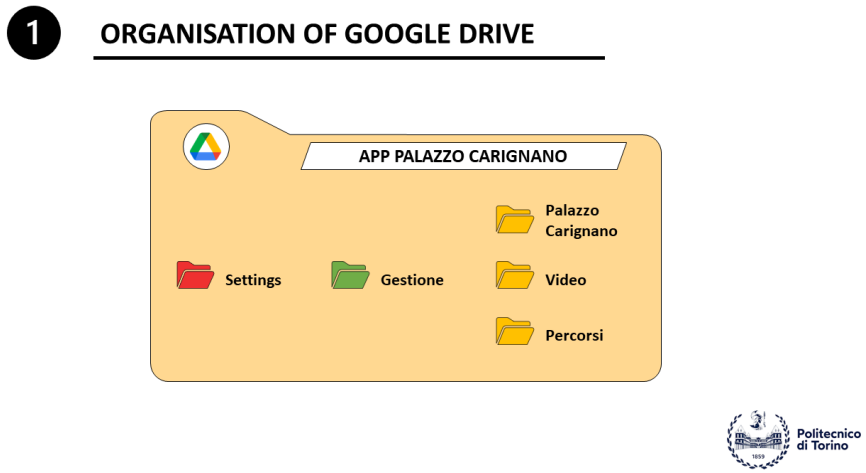


Figure A.2: Guide for Museum Staff, page 2.

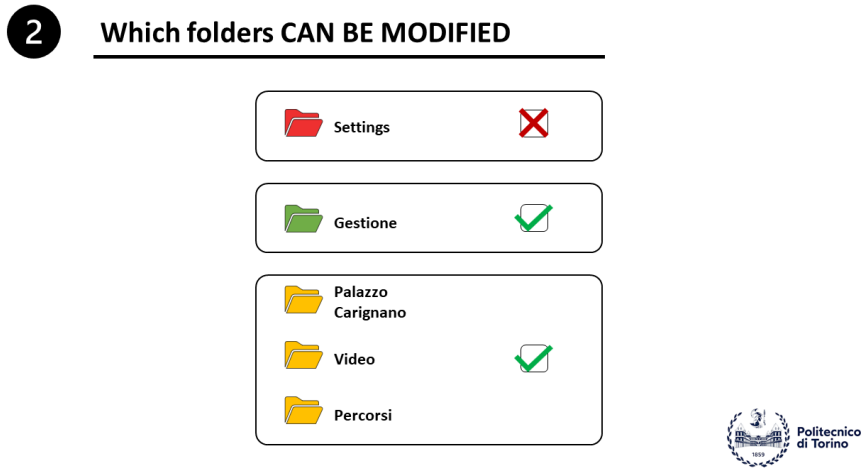


Figure A.3: Guide for Museum Staff, page 3.

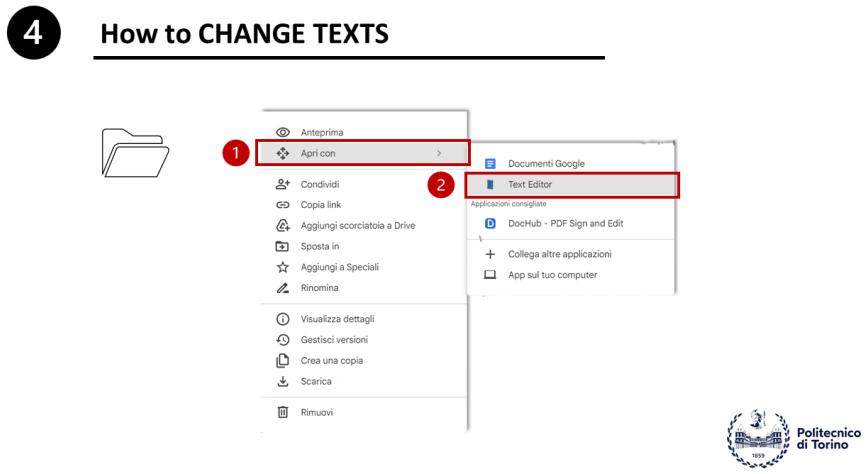


Figure A.4: Guide for Museum Staff, page 4.

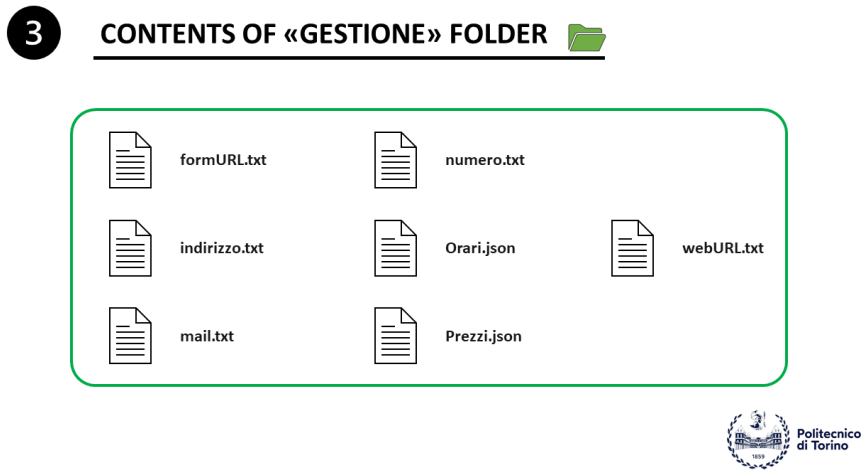


Figure A.5: Guide for Museum Staff, page 5.

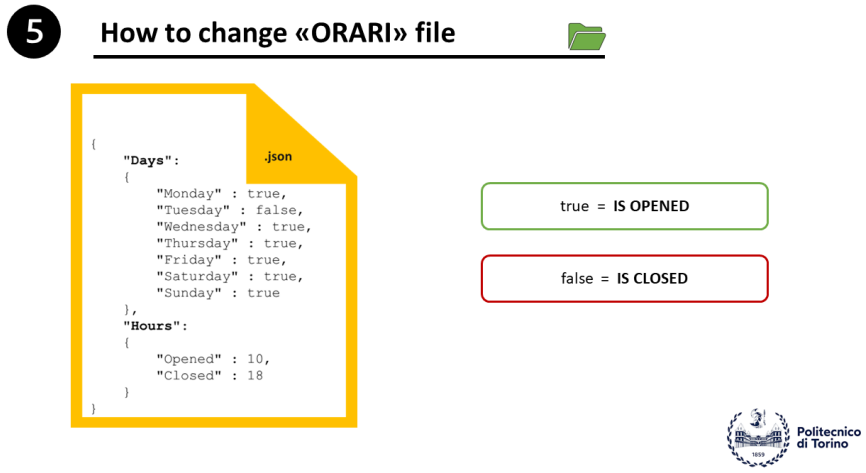


Figure A.6: Guide for Museum Staff, page 6.

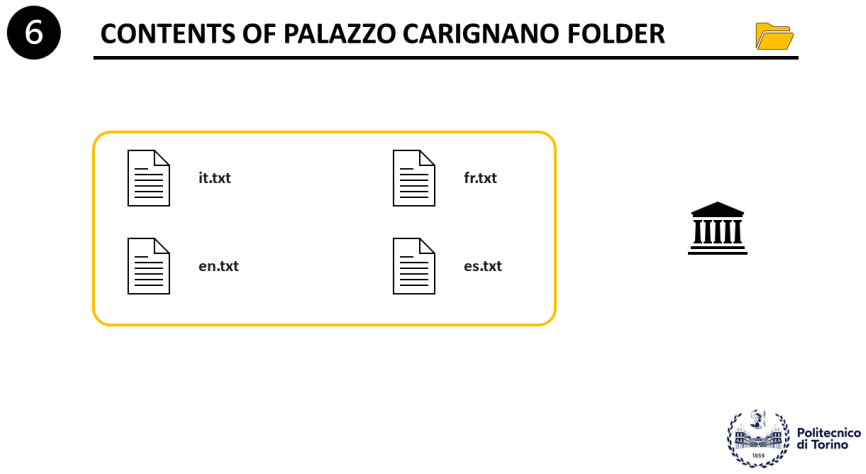


Figure A.7: Guide for Museum Staff, page 7.

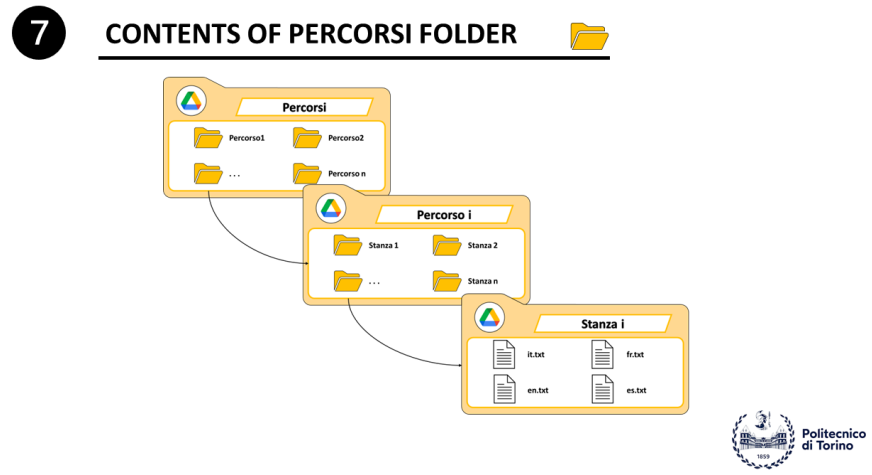


Figure A.8: Guide for Museum Staff, page 8.

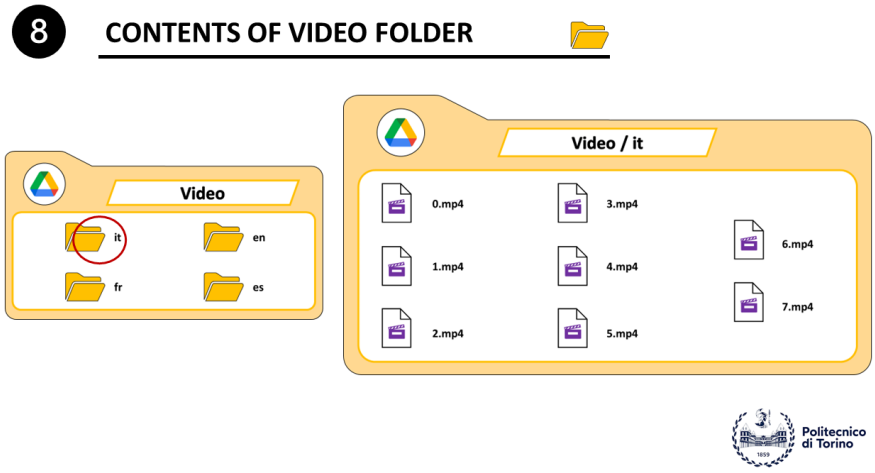


Figure A.9: Guide for Museum Staff, page 9.

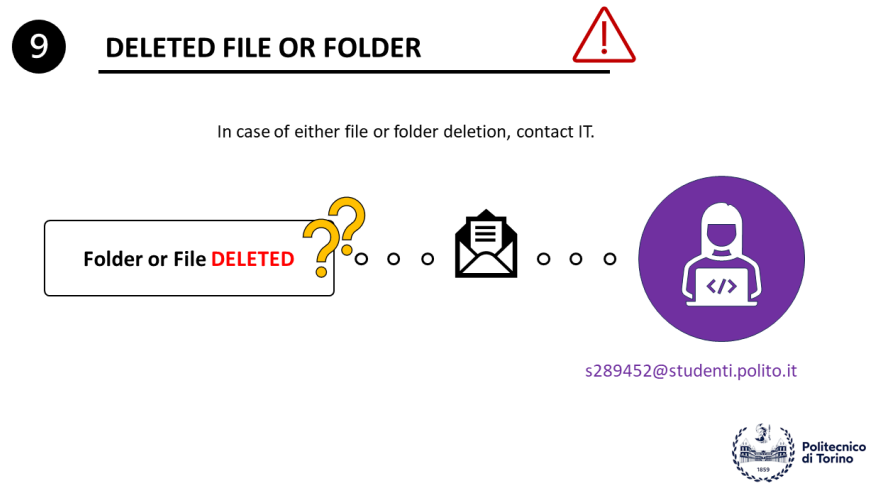


Figure A.10: Guide for Museum Staff, page 10.

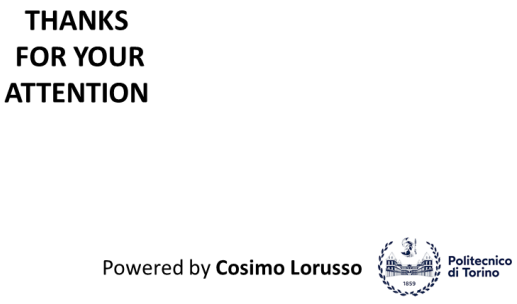


Figure A.11: Guide for Museum Staff, page 11.

Appendix B

Guide for Users

This guide illustrates how use the mobile app at end users, so as to facilitate usability and navigability within the app. The guide is written using the AAC with ARASACC symbols.

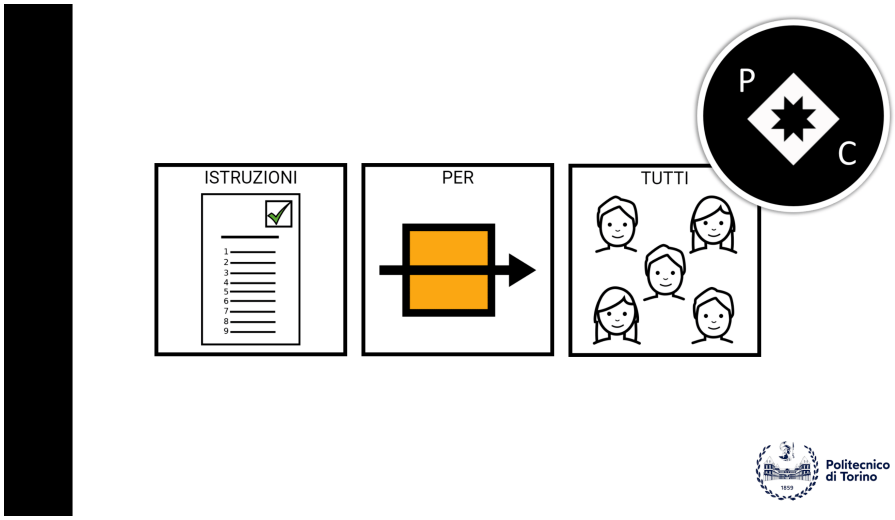


Figure B.1: Guide for users, page 1.

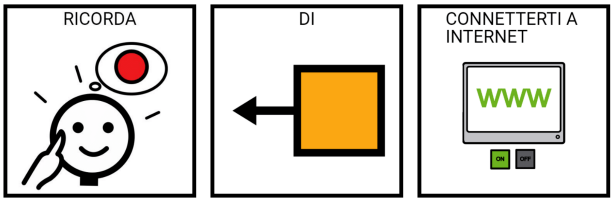


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Figure B.2: Guide for users, page 2.

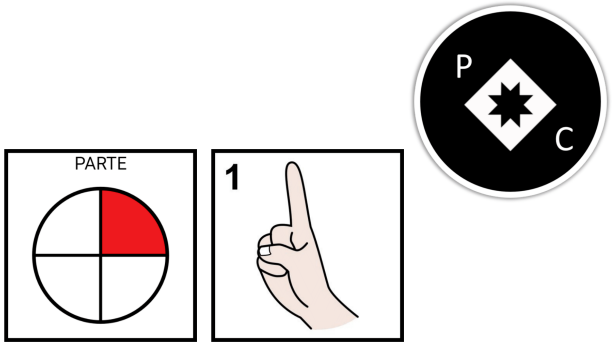

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Figure B.3: Guide for users, page 3.

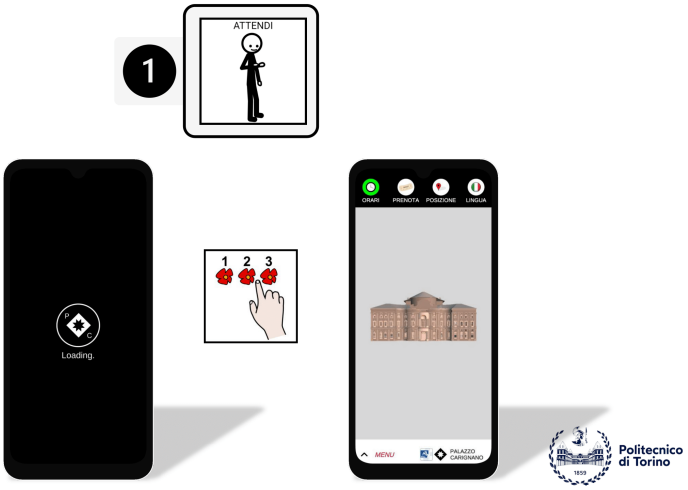

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Figure B.4: Guide for users, page 4.

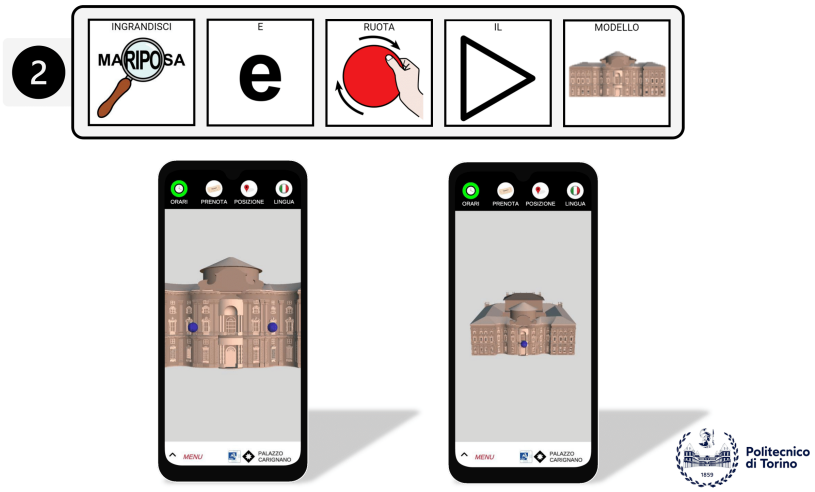

Figure B.5: Guide for users, page 5.

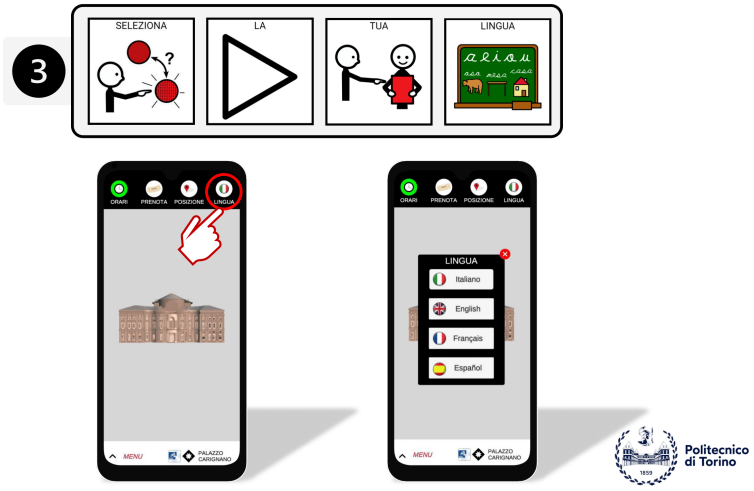

Figure B.6: Guide for users, page 6.

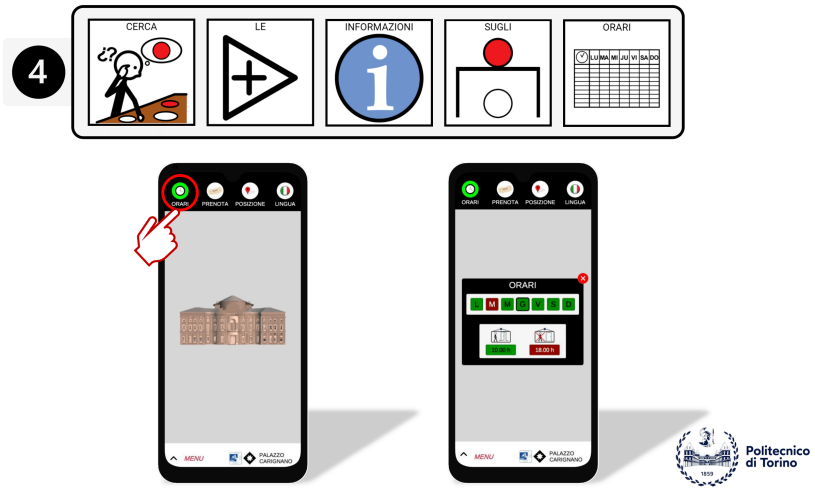

Figure B.7: Guide for users, page 7.

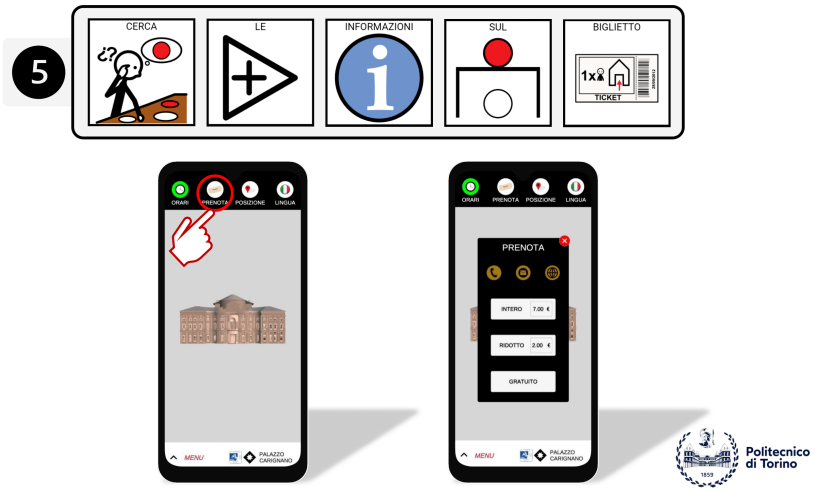

Figure B.8: Guide for users, page 8.

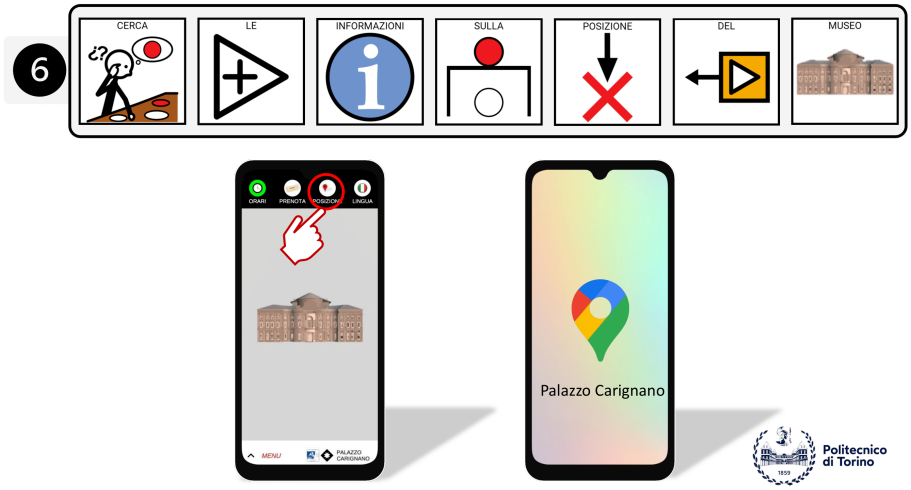

Figure B.9: Guide for users, page 9.

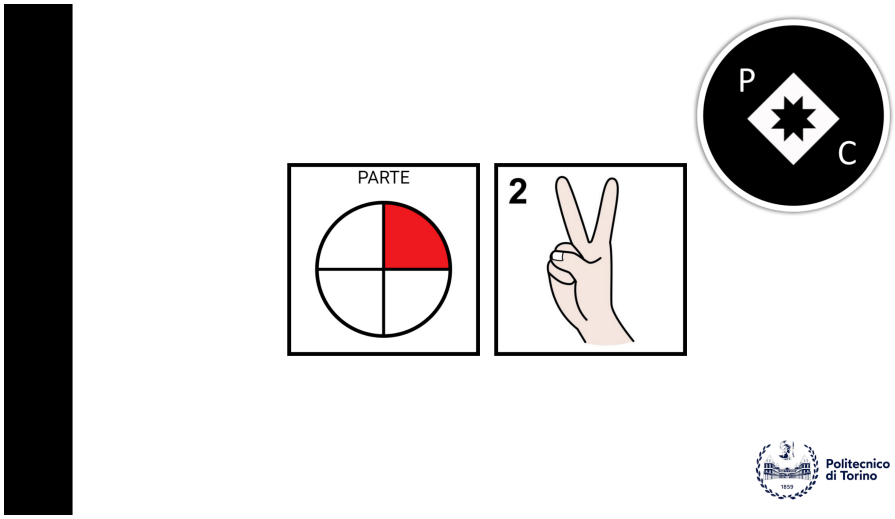

Figure B.10: Guide for users, page 10.

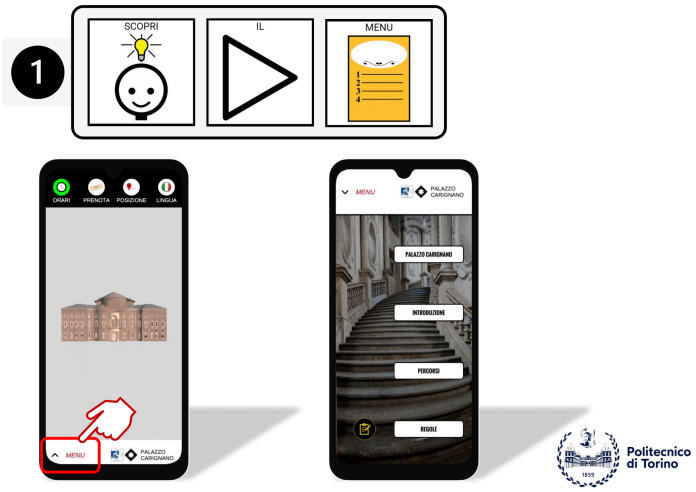

Figure B.11: Guide for users, page 11.

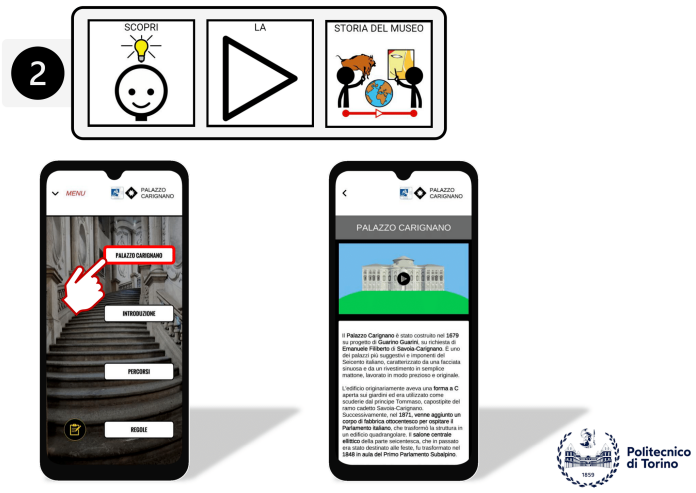

Figure B.12: Guide for users, page 12.

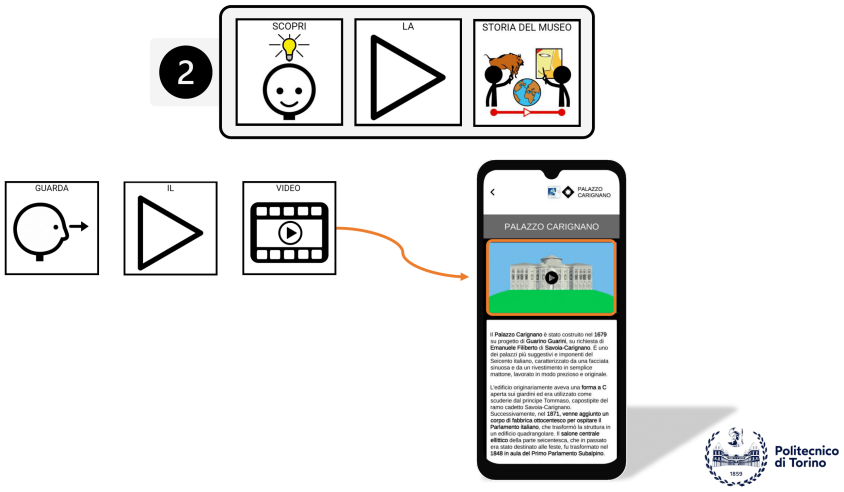

Figure B.13: Guide for users, page 13.

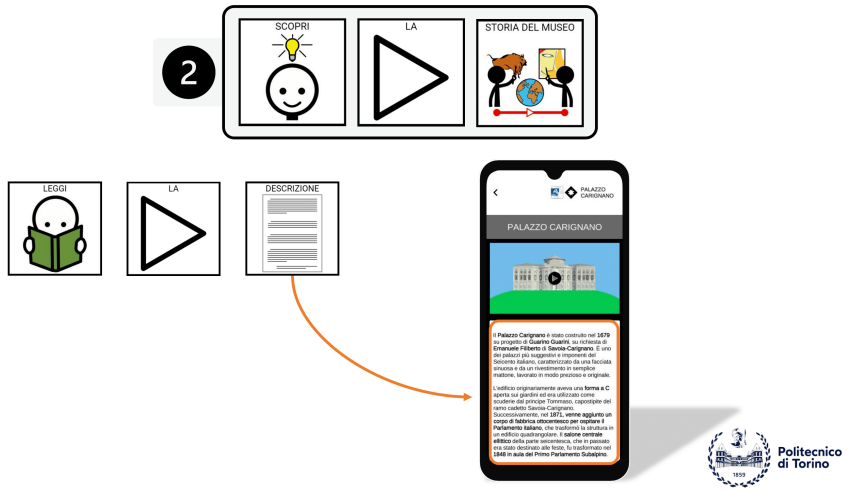

Figure B.14: Guide for users, page 14.

Figure B.15: Guide for users, page 15.

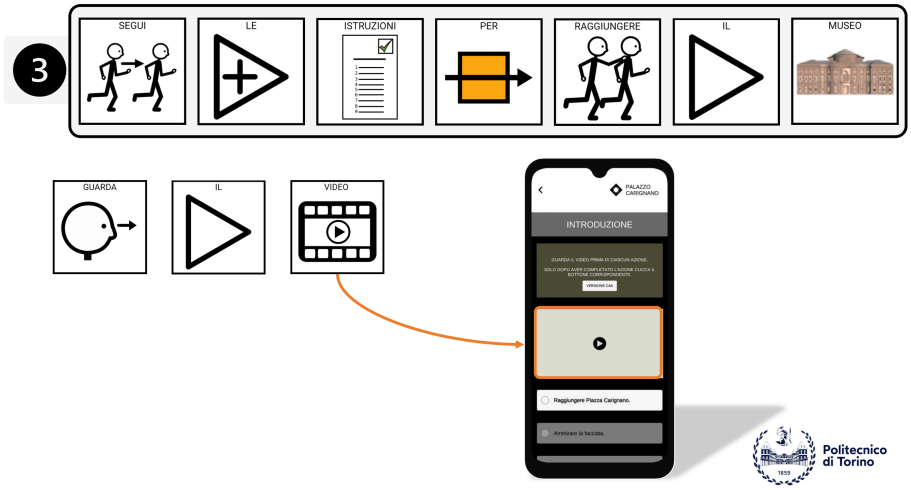

Figure B.16: Guide for users, page 16.

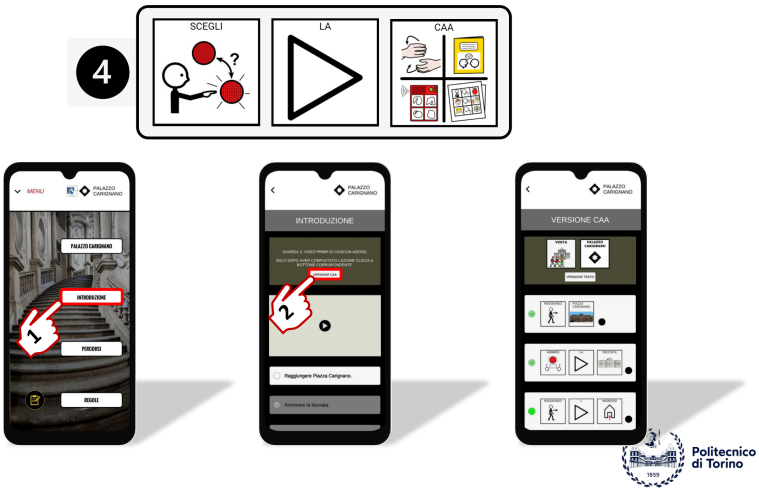

Figure B.17: Guide for users, page 17.

Figure B.18: Guide for users, page 18.

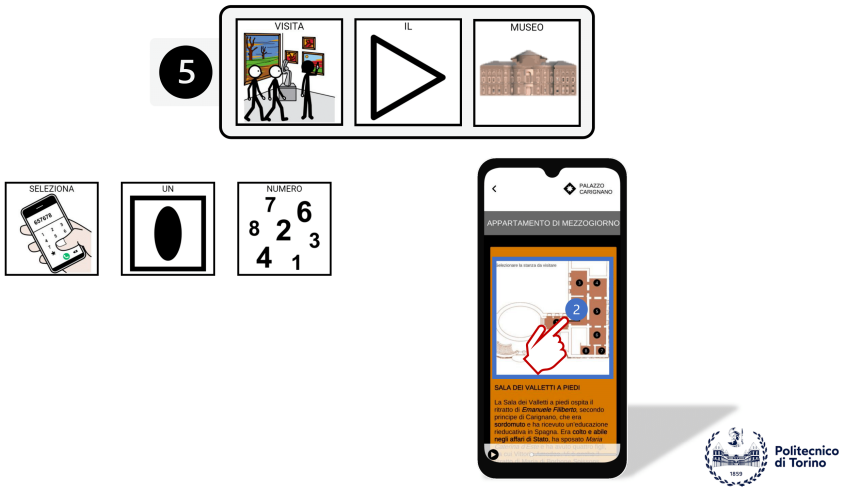

Figure B.19: Guide for users, page 19.

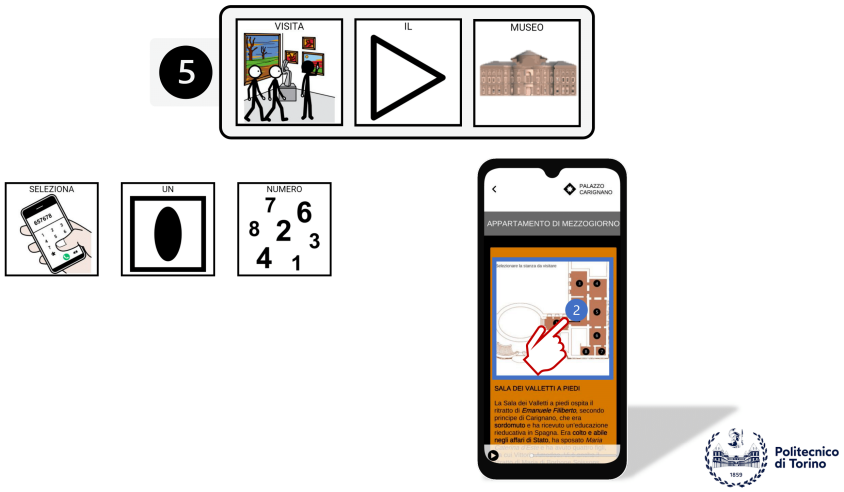

Figure B.20: Guide for users, page 19.

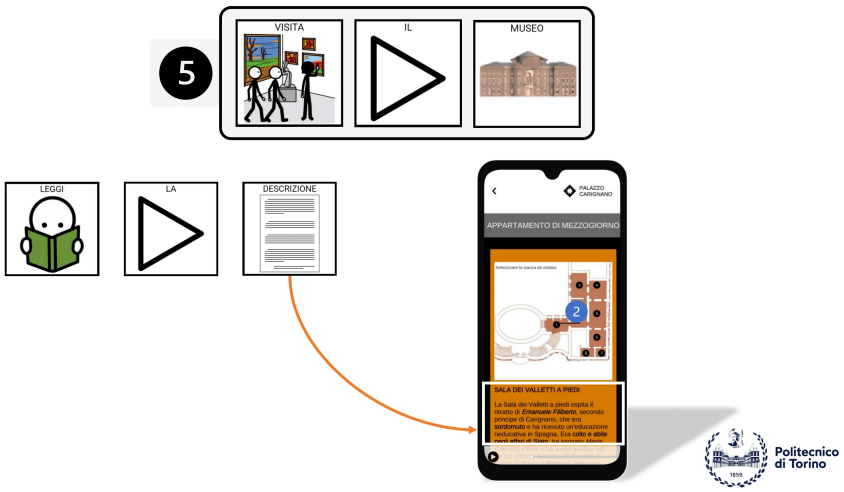

Figure B.21: Guide for users, page 20.

Figure B.22: Guide for users, page 21.

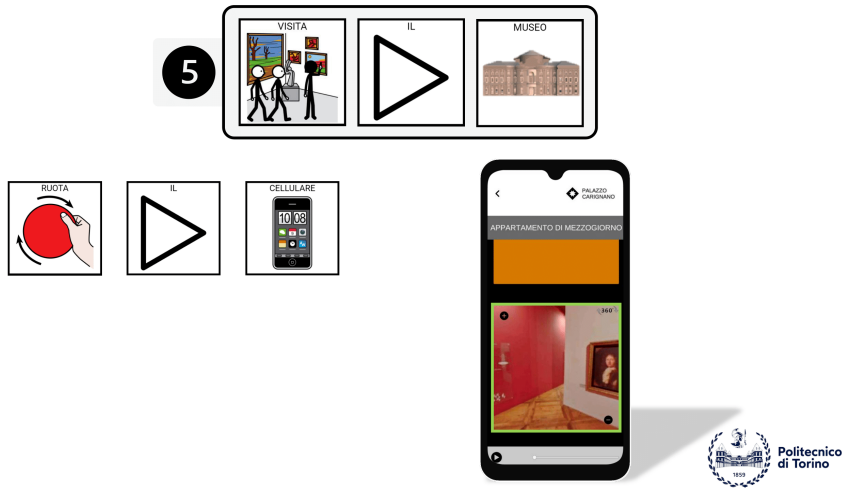

Figure B.23: Guide for users, page 22.

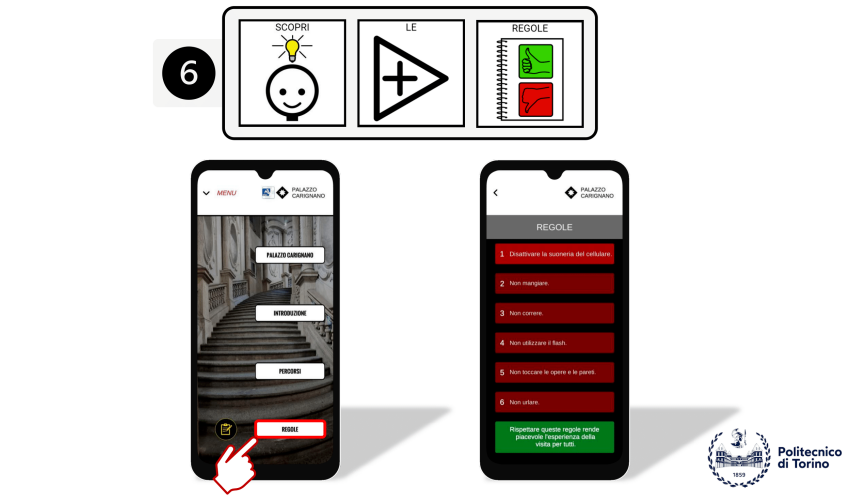

Figure B.24: Guide for users, page 23.

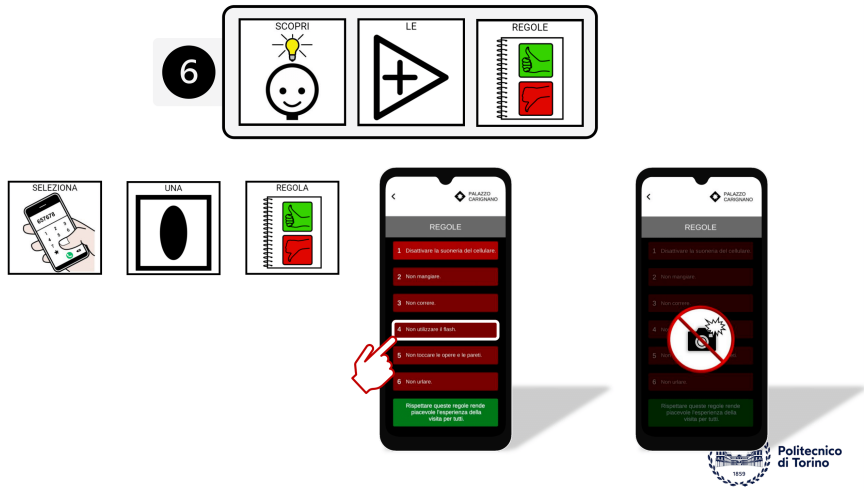

Figure B.25: Guide for users, page 24.

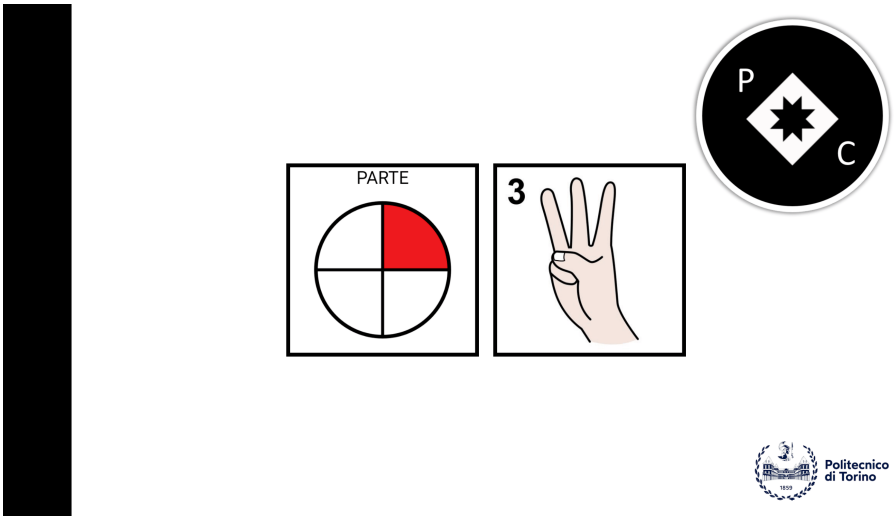

Figure B.26: Guide for users, page 25.

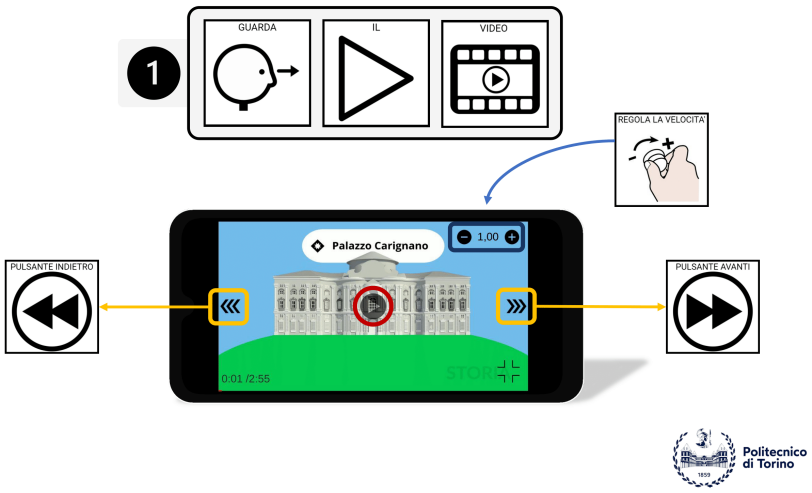

Figure B.27: Guide for users, page 26.

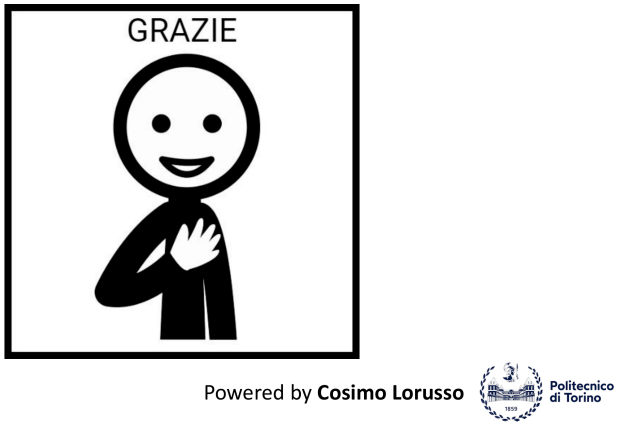

Figure B.28: Guide for users, page 27.

Appendix C

Guide for IT staff

This guide (collection of scripts) is intended to leave a legacy for future developers of the application so as to reduce the risk of obsolescence and system failure.

Listing C.1: IFCDataLoader.cs script - it allows each child of the parent GameObject (BIM) to be associated with the correct name, the GUID in the ID section is saved, and also all the associated properties by exploiting the relationships in the XML file.

```
1  using UnityEngine;
2  using System.Collections.Generic;
3  using System.Xml;
4  using System;
5
6  public class IFCDataLoader : MonoBehaviour
7  {
8      public string xmlFilePath =
          "Assets/Environment/Carignano/HBim.xml";
9      public XmlDocument xmlDoc;
10
11     void Awake()
12     {
13         xmlDoc = new XmlDocument();
14         xmlDoc.Load(xmlFilePath);
15
16         foreach (Transform child in transform)
17         {
18             string targetBuildingElementId = child.name;
19             if
                  (!string.IsNullOrEmpty(targetBuildingElementId))
20             {
21                 LoadDataFromXML(targetBuildingElementId,
                      child);
22             }
23             else
24             {
```

```
25                  Debug.LogError("Please specify the
                       target IfcBuildingElement ID.");
26              }
27          }
28      }
29
30
31      void LoadDataFromXML(string targetBuildingElementId,
           Transform child)
32      {
33          try
34          {
35              XmlNode targetNode =
                   xmlDoc.SelectSingleNode($"//*[@id='{targetBuildingEleme
36
37              if (targetNode != null)
38              {
39                  child.name =
                       targetNode.Attributes["Name"].Value;
40
41                  // Assign the targetBuildingElement to
                       the child GameObject
42                  IfcBuildingElement
                       buildingElementComponent =
                       child.gameObject.AddComponent<IfcBuildingElement>()
43                  buildingElementComponent.Id =
                       targetBuildingElementId;
44
45                  XmlNodeList propertySetNodes =
                       targetNode.SelectNodes(".//IfcPropertySet");
46
47                  foreach (XmlNode propertySetNode in
                       propertySetNodes)
48                  {
49                      IfcPropertySet propertySet = new
                           IfcPropertySet();
50                      propertySet =
                           LoadPropertyFromXML(propertySetNode.Attributes
51                      buildingElementComponent.Properties.Add(propertyS
52                  }
53
54              }
55              else
56              {
```

```
57                  Debug.LogError($"No IfcBuildingElement
                       found with ID:
                       {targetBuildingElementId}");
58              }
59          }
60          catch (Exception e)
61          {
62              Debug.LogError($"Error loading XML:
                   {e.Message}");
63          }
64      }
65
66      public IfcPropertySet LoadPropertyFromXML(string
           propertySetId)
67      {
68          IfcPropertySet propertySet = new
               IfcPropertySet();
69
70          try
71          {
72              XmlNode propertySetNode =
                   xmlDoc.SelectSingleNode($"//*[@id='{propertySetId}']");
73
74              if (propertySetNode != null)
75              {
76                  propertySet.Name =
                       propertySetNode.Attributes["Name"].Value;
77
78                  XmlNodeList propertyNodes =
                       propertySetNode.SelectNodes(".//IfcPropertySingleVa
79
80                  foreach (XmlNode propertyNode in
                       propertyNodes)
81                  {
82                      string propertyName =
                           propertyNode.Attributes["Name"]?.Value;
83                      string propertyValue =
                           propertyNode.Attributes["NominalValue"]?.Value;
84
85                      IfcProperty property = new
                           IfcProperty
86                      {
87                          Name = propertyName,
88                          Value = propertyValue
89                      };
90
```

```
91                      propertySet.Properties.Add(property);
92                  }
93              }
94              else
95              {
96                  Debug.LogError($"No IfcPropertySet found
                       with ID: {propertySetId}");
97              }
98          }
99          catch (Exception e)
100         {
101             Debug.LogError($"Error loading property set
                   from XML: {e.Message}");
102         }
103
104         return propertySet;
105     }
106 }
```

Listing C.2: SceneChanger.cs script - Through the sceneName string, it is possible to change scenes when a button is pressed by the user.

```
1  // Import the directives
2  using UnityEngine;
3  using UnityEngine.SceneManagement;
4
5  public class SceneChanger : MonoBehaviour
6  {
7      public void ChangeScene(string sceneName)
8      {
9          SceneManager.LoadScene(sceneName); // Load the
               scene with the specified name
10     }
11 }
```

Listing C.3: ResourceRequester.cs script -

```
1  // Import the directives
2  using System.Collections;
3  using System.Collections.Generic;
4  using UnityEngine;
5  using UnityEngine.UI;
6  using UnityEngine.Networking;
7  using UnityEngine.SceneManagement;
8  using Newtonsoft.Json;
9
10 public class ResourceRequester : MonoBehaviour
11     {
```

```
12          public static ResourceRequester Instance; //
               Create an Istance of ResourceRequester
13
14          public string serverUrl; // Replace with your
               server URL
15          public float requestDelay = 1f; // Delay between
               consecutive requests
16          public string[] resourceIds; // List of resource
               IDs
17          public string idDrive = "XXXX";
18          public List<string> fetchedResources; // List to
               store the fetched resources
19
20          private bool isOK = false;
21          private Coroutine fetchCoroutine;
22          private GameObject loadingObject;
23          private Text loadingText;
24          private float dotInterval = 0.5f;
25
26          private void Awake()
27          {
28              if (Instance != null)
29              {
30                  Destroy(gameObject);
31                  return;
32              }
33              Instance = this;
34              DontDestroyOnLoad(gameObject);
35          }
36
37          private void Start()
38          {
39              loadingObject = GameObject.Find("TextColor");
40              loadingText =
                   loadingObject.GetComponent<Text>();
41
42              // Load the server URL from a text asset
43              serverUrl =
                   Resources.Load<TextAsset>("urlDownload").text;
44
45              // Start fetching the data and populate the
                   resource IDs
46              StartCoroutine(AnimateLoadingText());
47              fetchCoroutine =
                   StartCoroutine(GetDataHandling(serverUrl
                   + idDrive, 2));
```

```
48
49          }
50
51          private IEnumerator WaitForDataAndSendRequests()
52          {
53              yield return new WaitUntil(() => isOK); //
                    Wait until the data is fetched and
                    processed
54
55              // Start sending requests to fetch the
                    resources
56              StartCoroutine(SendRequests());
57          }
58
59          private IEnumerator SendRequests()
60          {
61              fetchedResources = new List<string>();
62
63              for (int i = 0; i < resourceIds.Length; i++)
64              {
65                  string resourceId = resourceIds[i];
66                  string requestUrl = serverUrl +
                        resourceId;
67
68                  UnityWebRequest request =
                        UnityWebRequest.Get(requestUrl);
69                  yield return request.SendWebRequest();
70
71                  if (request.result ==
                        UnityWebRequest.Result.Success)
72                  {
73                      string resourceData =
                            request.downloadHandler.text;
74                      fetchedResources.Add(resourceData);
75                      Debug.Log("Received resource: " +
                            resourceData);
76                  }
77                  else
78                  {
79                      Debug.LogError("Error fetching
                            resource: " + request.error);
80                  }
81
82                  request.Dispose();
83
```

```
84                  yield return new
                       WaitForSeconds(requestDelay);
85              }
86
87              // All requests completed
88              Debug.Log("All resources fetched. Total: " +
                   fetchedResources.Count);
89
90              // Do further processing with the fetched
                   resources as needed
91              // For example, you can iterate over the
                   fetchedResources list and perform
                   operations on each resource.
92              // Check if all resources are downloaded
                   correctly
93              if (fetchedResources.Count ==
                   resourceIds.Length)
94              {
95                  // Load the next scene if all resources
                       are downloaded correctly
96                  LoadNextScene();
97              }
98              else
99              {
100                 StopCoroutine(AnimateLoadingText());
101
102                 GameObject panelObject =
                       GameObject.Find("PanelColor");
103                 if(panelObject != null)
104                 {
105                     Color CloseColor;
106                     ColorUtility.TryParseHtmlString("#931100",
                           out CloseColor);
107                     panelObject.GetComponent<Image>().color
                           = CloseColor;
108
109                     loadingText.text = "Restart the app";
110
111                 }
112
113
114                 ShowInternetConnectionMessage();
115             }
116         }
117
```

```
118         private IEnumerator GetDataHandling(string url,
                int maxRetryCount)
119         {
120             int retryCount = 0;
121 
122             while (retryCount < maxRetryCount)
123             {
124                 UnityWebRequest request =
                        UnityWebRequest.Get(url);
125                 yield return request.SendWebRequest();
126 
127                 if (request.result ==
                        UnityWebRequest.Result.Success)
128                 {
129                     // Deserialize the JSON data into a
                            Dictionary
130                     Dictionary<string, string> data =
                            JsonConvert.DeserializeObject<Dictionary<string
                            string>>(request.downloadHandler.text);
131                     resourceIds =
                            ExtractDictionaryValues(data);
132                     isOK = true;
133 
134                     // Start sending requests to fetch
                            the resources after the data is
                            fetched
135                     StartCoroutine(WaitForDataAndSendRequests());
136 
137                     yield break; // Break out of the
                            loop if the request is successful
138                 }
139                 else
140                 {
141                     // Handle the error if the request
                            fails
142                     Debug.Log("Error fetching data.
                            Retrying...");
143                     retryCount++;
144                     yield return new
                            WaitForSeconds(requestDelay);
145                 }
146 
147                 request.Dispose();
148             }
149 
```

```
150             // Maximum retry count reached, handle the
                   error
151             Debug.Log("Max retry count reached. Unable
                   to fetch data.");
152
153             StopCoroutine(AnimateLoadingText());
154
155             GameObject panelObject =
                   GameObject.Find("PanelColor");
156             if(panelObject != null)
157             {
158                 Color CloseColor;
159                 ColorUtility.TryParseHtmlString("#931100",
                       out CloseColor);
160                 panelObject.GetComponent<Image>().color
                       = CloseColor;
161
162                 loadingText.text = "Restart the app";
163
164             }
165
166         }
167
168
169         private string[] ExtractDictionaryValues<TKey,
                TValue>(Dictionary<TKey, TValue> dictionary)
170         {
171             string[] values = new
                   string[dictionary.Values.Count];
172             int index = 0;
173
174             foreach (TValue value in dictionary.Values)
175             {
176                 values[index] = value.ToString();
177                 index++;
178             }
179
180             return values;
181         }
182
183         private void ShowInternetConnectionMessage()
184         {
185             // Display a message indicating that the
                   internet connection must be activated
186             Debug.Log("Please activate the internet
                   connection to fetch resources.");
```

```
187         }
188
189         private void LoadNextScene()
190         {
191             // Load the next scene
192             SceneManager.LoadScene("Menu");
193         }
194
195         private IEnumerator AnimateLoadingText()
196         {
197             int dotCount = 0;
198
199             while (true)
200             {
201                 string dots = new string('.', dotCount %
                        4);
202
203                 if (loadingText != null)
204                 {
205                     loadingText.text = "Loading" + dots;
206                 }
207
208                 yield return new
                        WaitForSeconds(dotInterval);
209
210                 dotCount++;
211             }
212         }
213
214     }
```

Listing C.4: swipeRotate.cs script - Based on the number of Input . touchCount and relative position goes to zoom or rotate the model.

```
using UnityEngine;

public class swipeRotate : MonoBehaviour
{

    public Camera Camera;

    public float rotateSeedMoifier = 0.2f;
    public float perspectiveZoomSpeed = .05f;
    public float minFoV = 20.0f;
    public float maxFoV = 60.0f;

    private Touch touch;
    private Vector2 touchPosition;
    private Quaternion rotationY;


    // Update is called once per frame
    void Update()
    {

        ///     ROTATION
        if(Input.touchCount ==1)
        {
            touch = Input.GetTouch(0);
            // Control if object is touched
            Ray ray =
               Camera.ScreenPointToRay(Input.touches[0].position);
            RaycastHit hit;
            if(Physics.Raycast(ray, out hit))
            {
                if(hit.collider != null && touch.phase
                   == TouchPhase.Moved)
                {
                    rotationY =
                       Quaternion.Euler(touch.deltaPosition.y
                       * rotateSeedMoifier, -
                       touch.deltaPosition.x *
                       rotateSeedMoifier, 0f);
                    transform.rotation = rotationY *
                       transform.rotation;
                }
            }
        }
```

```
38
39          ///     ZOOM
40
41          if (Input.touchCount >= 2)
42          {
43              Touch touchZero = Input.GetTouch(0);
44              Touch touchOne = Input.GetTouch(1);
45
46              Vector2 touchZeroPrevPos =
                   touchZero.position -
                   touchZero.deltaPosition;
47              Vector2 touchOnePrevPos = touchOne.position
                   - touchOne.deltaPosition;
48
49              // Control if object is touched
50              Ray ray =
                   Camera.ScreenPointToRay(Input.touches[0].position);
51              RaycastHit hit;
52              if(Physics.Raycast(ray, out hit))
53              {
54                  if(hit.collider != null)
55                  {
56                      float prevTouchDeltaMag =
                           (touchZeroPrevPos -
                           touchOnePrevPos).magnitude;
57                      float touchDeltaMag =
                           (touchZero.position -
                           touchOne.position).magnitude;
58
59                      float deltaMagnitudediff =
                           prevTouchDeltaMag - touchDeltaMag;
60                      Camera.fieldOfView +=
                           deltaMagnitudediff *
                           perspectiveZoomSpeed;
61                      Camera.fieldOfView =
                           Mathf.Clamp(Camera.fieldOfView,
                           minFoV, maxFoV);
62                  }
63              }
64          }
65
66      }
67  }
```

Listing C.5: VariableControl.cs script

```
using System.IO;
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using UnityEngine.Networking;
using UnityEngine.SceneManagement;
using Newtonsoft.Json;

public class VariableControl : MonoBehaviour
{
    public static VariableControl Instance;
    public bool state;              // new variable declared
    public int count;
    public string lang;
    public string functionality;

    private string driveURL = "https://drive.google.com/uc?export=download&id=";
    private int currentIndex;
    private string folderPath;
    private string jsonData;
    private List<string> videoDownloadLinks;

    private void Awake()
    {
        // start of new code
        if (Instance != null)
        {
            Destroy(gameObject);
            return;
        }
        // end of new code

        Instance = this;

        // Load the JSON data from Resources
        jsonData = Resources.Load<TextAsset>("video").text;

        DontDestroyOnLoad(gameObject);
    }

    private void Start()
```

```
43      {
44          state = false;
45          count = 0;
46      }
47
48      public void UgradeState(bool newstate)
49      {
50          state = newstate;
51          count += 1;
52      }
53
54      public void UpdateFunctionality(string
            FunctionalityName)
55      {
56          functionality = FunctionalityName;
57      }
58
59      // The CreateFolderVideo method creates a folder to
            store videos
60      // based on the specified language (lang) and
            functionality.
61      public void CreateFolderVideo()
62      {
63          currentIndex = 0;
64
65          // Set the folder path for storing the video
66          folderPath = Path.Combine(Application.platform ==
67              RuntimePlatform.Android ||
                    Application.platform ==
68              RuntimePlatform.IPhonePlayer ?
69              Application.persistentDataPath :
                    Application.dataPath,
70              "video", lang);
71
72          // Create the folder path if it doesn't exist
73          if (!Directory.Exists(folderPath))
74          {
75              Directory.CreateDirectory(folderPath);
76          }
77
78          //video
79
80          // Read the desired filename from the JSON data
                based on functionality
81          string videos = JsonParser.ReadJson(jsonData,
                lang);
```

```
82
83          Dictionary<string, string> videoDict =
               JsonConvert.DeserializeObject<Dictionary<string,
               string>>(videos);
84
85          // Retrieve all values from the dictionary
86          videoDownloadLinks = new
               List<string>(videoDict.Values);
87
88          DownloadNextVideo();
89      }
90
91
92      private void DownloadNextVideo()
93      {
94          if (currentIndex >= videoDownloadLinks.Count)
95          {
96              Debug.Log("All videos downloaded!");
97              return;
98          }
99
100
101         string videoPath = Path.Combine(folderPath,
               currentIndex.ToString() + ".mp4");
102
103         if (File.Exists(videoPath))
104         {
105             Debug.Log("Video already exists: " +
                   videoPath);
106             currentIndex++;
107             DownloadNextVideo();
108         }
109         else
110         {
111             StartCoroutine(DownloadVideo(videoDownloadLinks[currentIn
                   currentIndex));
112             currentIndex++;
113         }
114     }
115
116     // It handles the download of videos from specified
           download links. It // checks if the video already
           exists locally and downloads it only if //
           necessary. The video download process is
           asynchronous and includes
117     // error handling.
```

```
118     private IEnumerator DownloadVideo(string
            downloadLink, int ind)
119     {
120         downloadLink = driveURL + downloadLink;
121 
122         UnityWebRequest request =
                UnityWebRequest.Get(downloadLink);
123 
124         yield return request.SendWebRequest();
125 
126         if (request.result ==
                UnityWebRequest.Result.Success)
127         {
128             string savePath =
                    Path.Combine(folderPath,ind.ToString()+".mp4");
                     // Specify the desired save path for the
                    video
129 
130             System.IO.File.WriteAllBytes(savePath,
                    request.downloadHandler.data);
131 
132             Debug.Log("Video downloaded successfully: "
                    + downloadLink);
133 
134             // Proceed to the next download
135             DownloadNextVideo();
136         }
137         else
138         {
139             Debug.LogError("Video download failed: " +
                    downloadLink + "\nError: " +
                    request.error);
140         }
141     }
142 }
```

Listing C.6: Room.cs script - Create a class for each room with the proprety indicates inside the code.

```
using System;
using System.IO;
using UnityEngine;
using UnityEngine.UI;

namespace Assets.Scripts.PathMuseum
{
        [Serializable]
        public class Room
        {
                public string Name; // name of room
                public string Path; // path of belonging

                public Sprite ImageButton;
            public Sprite ImageHButton;
            public Texture Plant;
            public Material Material;
                public string Description; // text
                   description or ID file

                public GameObject Button; // Button
                   associated
                public bool status;       // IsSelected
        }
}
```

Listing C.7: MyVideoPlay.cs script - Manages videos within the application. Allows increasing or decreasing playback speed and time. Also allows full-screen or reduced viewing.

```
using System;
using System.IO;
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.Video;
using UnityEngine.UI;
using UnityEngine.SceneManagement;
using Assets.Scripts.ToggleScript;

namespace Assets.Scripts
{
    public class MyVideoPlay : MonoBehaviour
    {
        [Header("Settings")]
        public SetVideoUrl videoPlayerController; // Reference to a video player controller script

        // Various private variables to store references to UI elements and control video playback
        private VideoPlayer videoPlayer;
        private Canvas Canvas;
        private GameObject contentPanel;
        private GameObject RowImage;
        private GameObject cinemaPlane;
        private GameObject progressBar;
        private GameObject MenuVideo;
        private GameObject btnFirstPlay;
        private GameObject btnPlay;
        private GameObject btnPause;
        private GameObject btnFScreen;
        private GameObject txtVelocity;
        private GameObject btnVelocityP;
        private GameObject btnVelocityM;
        private GameObject btnPlus;
        private GameObject btnMinus;
        private GameObject txtTime;

        // Flags and variables for managing video playback and UI
        private bool videoIsPlaying = false;
        private bool videoIsFirstPlaying = false;
        public bool fullIsClicked = false;
```

```
41          private bool videoMenu = false;
42          private float levelVelocity = 1f;
43          private float scale;
44          public int indexVideo;
45          private DeviceOrientation previousOrientation;
46          private ScreenOrientation
               previousScreenOrientation;
47          public int indexMax;
48          private Sprite spriteFull;
49          private Sprite spriteReduce;
50
51          private void Awake()
52          {
53              // Load sprite resources for full-screen and
                   reduce-screen buttons
54              spriteFull =
                   Resources.Load<Sprite>(Path.Combine("VideoSprite",
                   "full"));
55              spriteReduce =
                   Resources.Load<Sprite>(Path.Combine("VideoSprite",
                   "reduce"));
56          }
57
58          void Start()
59          {
60              previousOrientation =
                   DeviceOrientation.LandscapeLeft;
61
62              // Initialize video components and configure
                   initial video settings
63              InitializeVideoComponents();
64
65              // Determine the current scene and adjust
                   the video index accordingly
66              if (SceneManager.GetActiveScene().name ==
                   "Scene 2" ||
                   SceneManager.GetActiveScene().name ==
                   "Scene 2a")
67              {
68                  indexVideo =
                       this.transform.parent.GetComponent<ManageToogles>()
69              }
70
71              ChangeVideoIndex();
72              StartWhenUWant();
73              MenuVideo.SetActive(false);
```

```
74
75              // Add a click listener to the first play
                   button
76              Button BtnFPlay =
                   btnFirstPlay.GetComponent<Button>();
77              BtnFPlay.onClick.AddListener(delegate {
                   videoIsPlaying = true; BtnPlayVideo(); if
                   (videoIsFirstPlaying == false) {
                   AddListenerAtAllButtonsVideo();
                   videoIsFirstPlaying = true; }
                   btnFirstPlay.SetActive(false);
                   HideFullScreen(fullIsClicked = true,
                   previousOrientation); });
78          }
79
80          // Method to change the video index
81          public void ChangeVideoIndex()
82          {
83              videoPlayerController.SetVideoByIndex(indexVideo);
84          }
85
86          void Update()
87          {
88              float progressBarWidth =
                   RowImage.GetComponent<RectTransform>().rect.width;
89
90              // Calculate and display video time progress
91              int minutes =
                   Mathf.FloorToInt((float)videoPlayer.time
                   / 60F);
92              int seconds =
                   Mathf.FloorToInt((float)videoPlayer.time
                   - minutes * 60);
93
94              float lengthy = (float)videoPlayer.length;
95              int minutes_tot =
                   Mathf.FloorToInt((float)lengthy / 60F);
96              int seconds_tot =
                   Mathf.FloorToInt((float)lengthy -
                   minutes_tot * 60);
97
98              string niceTime = string.Format("
                   {0:0}:{1:00} /{2:0}:{3:00}", minutes,
                   seconds, minutes_tot, seconds_tot);
99              txtTime.GetComponent<Text>().text = niceTime;
100
```

```
101             // Update the progress bar based on video
                   frame count
102             if (videoIsPlaying == true &&
                   videoPlayer.frameCount > 0)
103             {
104                 float progress =
                       (float)videoPlayer.frame /
                       (float)videoPlayer.frameCount;
105                 progressBar.transform.localScale = new
                       Vector3(progressBarWidth * progress,
                       progressBar.transform.localScale.y,
                       0);
106             }
107
108             if (videoIsPlaying == false &&
                   videoPlayer.frameCount > 0)
109             {
110                 float progress =
                       (float)videoPlayer.frame /
                       (float)videoPlayer.frameCount;
111                 progressBar.transform.localScale = new
                       Vector3(progressBarWidth * progress,
                       progressBar.transform.localScale.y,
                       0);
112             }
113
114             // Detect changes in device orientation
115             if (previousOrientation !=
                   Input.deviceOrientation)
116             {
117                 if (videoIsPlaying == false &&
                       videoIsFirstPlaying == true)
118                 {
119                     if (Input.deviceOrientation ==
                           DeviceOrientation.LandscapeLeft)
120                     {
121                         previousOrientation =
                               Input.deviceOrientation;
122                     }
123                     else if (Input.deviceOrientation ==
                           DeviceOrientation.LandscapeRight)
124                     {
125                         previousOrientation =
                               Input.deviceOrientation;
126                     }
127                     bool fullIsClickedMask = true;
```

```
128
129                     if (fullIsClicked ==
                           fullIsClickedMask)
130                     {
131                         HideFullScreen(fullIsClickedMask,
                               previousOrientation);
132                     }
133
134                     StartCoroutine(Temporary());
135
136                     previousOrientation =
                           Input.deviceOrientation;
137                 }
138             }
139
140             // Detect when the video has finished playing
141             if (videoPlayer.frame ==
                   (long)videoPlayer.frameCount - 1)
142             {
143                 VideoStop();
144
145                 fullIsClicked = false;
146
147                 HideFullScreen(fullIsClicked,
                       previousOrientation);
148                 StartWhenUWant();
149
150                 Button BtnFPlay =
                       btnFirstPlay.GetComponent<Button>();
151                 btnFirstPlay.SetActive(true);
152                 MenuVideo.SetActive(false);
153                 BtnFPlay.onClick.AddListener(delegate {
                       videoIsPlaying = true;
                       BtnPlayVideo(); if
                       (videoIsFirstPlaying == false) {
                       AddListenerAtAllButtonsVideo();
                       videoIsFirstPlaying = true; }
                       btnFirstPlay.SetActive(false);
                       HideFullScreen(fullIsClicked = true,
                       previousOrientation); });
154                 // Video has finished playing!
155             }
156         }
157
158         // Method to set up initial conditions for video
               playback
```

```
159         void StartWhenUWant()
160         {
161             if (indexMax != 0)
162             {
163                 this.GetComponent<RectTransform>().sizeDelta
                        = new Vector2(580, 324 * 580 / 594);
164             }
165 
166             cinemaPlane.SetActive(false);
167             MenuVideo.SetActive(false);
168             btnPause.SetActive(false);
169             btnPlay.SetActive(true);
170             videoPlayer.frame = (long)0;
171 
172             levelVelocity = (float)1;
173             videoPlayer.playbackSpeed = levelVelocity;
174             string niceTime = string.Format(" {0:0.00}",
                    levelVelocity);
175             txtVelocity.GetComponent<Text>().text =
                    niceTime;
176             this.transform.SetSiblingIndex(indexVideo +
                    1);
177 
178             StartCoroutine(PlayStart());
179         }
180 
181         // Method to initialize video components and UI
                elements
182         void InitializeVideoComponents()
183         {
184             Canvas =
                    transform.root.GetComponent<Canvas>();
185             videoPlayer = GetComponent<VideoPlayer>();
186             contentPanel =
                    GameObject.Find("BottomPanel").transform.GetChild(0).ga
187 
188             RowImage =
                    this.transform.GetChild(0).gameObject;
189             progressBar =
                    RowImage.transform.GetChild(0).gameObject;
190             MenuVideo =
                    RowImage.transform.GetChild(1).gameObject;
191 
192             btnPlay =
                    MenuVideo.transform.GetChild(0).gameObject;
```

```
193             btnPause =
                    MenuVideo.transform.GetChild(1).gameObject;
194             btnFScreen =
                    MenuVideo.transform.GetChild(2).gameObject;
195             txtVelocity =
                    MenuVideo.transform.GetChild(3).gameObject;
196             btnVelocityP =
                    MenuVideo.transform.GetChild(4).gameObject;
197             btnVelocityM =
                    MenuVideo.transform.GetChild(5).gameObject;
198             btnPlus =
                    MenuVideo.transform.GetChild(6).gameObject;
199             btnMinus =
                    MenuVideo.transform.GetChild(7).gameObject;
200             txtTime =
                    MenuVideo.transform.GetChild(8).gameObject;
201
202             btnFirstPlay =
                    this.transform.GetChild(1).gameObject;
203
204             cinemaPlane =
                    GameObject.Find("PanelFullVideo").gameObject;
205         }
206
207         // Method to add listeners to UI buttons for
                video control
208         void AddListenerAtAllButtonsVideo()
209         {
210             Button BtnV =
                    videoPlayer.GetComponent<Button>();
211             BtnV.onClick.AddListener(delegate {
                    MenuHide(); });
212
213             Button BVc =
                    btnVelocityP.GetComponent<Button>();
214             BVc.onClick.AddListener(delegate {
                    ChangeVelocityUp(); });
215
216             Button BVD =
                    btnVelocityM.GetComponent<Button>();
217             BVD.onClick.AddListener(delegate {
                    ChangeVelocityDown(); });
218
219             Button BtnP = btnPlay.GetComponent<Button>();
220             BtnP.onClick.AddListener(delegate {
                    BtnPlayVideo(); });
```

```
221
222             Button BtnPe =
                    btnPause.GetComponent<Button>();
223             BtnPe.onClick.AddListener(delegate {
                    BtnPlayVideo(); });
224
225             Button FScr =
                    btnFScreen.GetComponent<Button>();
226             FScr.onClick.AddListener(delegate {
                    fullIsClicked = !fullIsClicked;
                    HideFullScreen(fullIsClicked,
                    previousOrientation); });
227
228             Button Avn = btnPlus.GetComponent<Button>();
229             Avn.onClick.AddListener(delegate {
                    IncrementTimeTen(); });
230
231             Button Ind = btnMinus.GetComponent<Button>();
232             Ind.onClick.AddListener(delegate {
                    DecreaseTimeTen(); });
233         }
234
235         // Method to increment video playback time by 10
                seconds
236         void IncrementTimeTen()
237         {
238             videoPlayer.time = videoPlayer.time += 10.0;
239
240             float progress = (float)videoPlayer.frame /
                    (float)videoPlayer.frameCount;
241
242             if (videoPlayer.frame ==
                    (long)videoPlayer.frameCount - 1)
243             {
244                 VideoStop();
245             }
246         }
247
248         // Coroutine to wait for a brief time
249         private IEnumerator Temporary()
250         {
251             yield return new WaitForSeconds(10f);
252         }
253
254         // Method to decrement video playback time by 10
                seconds
```

```
255         void DecreaseTimeTen()
256         {
257             videoPlayer.time = videoPlayer.time -= 10.0;
258         }
259 
260         // Method to toggle the video menu visibility
261         void MenuHide()
262         {
263             videoMenu = !videoMenu;
264 
265             if (videoMenu == true)
266             {
267                 StartCoroutine(TimingMenuHide());
268             }
269             else
270             {
271                 MenuVideo.SetActive(false);
272             }
273         }
274 
275         // Coroutine to hide the video menu after a delay
276         private IEnumerator TimingMenuHide()
277         {
278             MenuVideo.SetActive(true);
279             yield return new WaitForSeconds(10f);
280             MenuVideo.SetActive(false);
281         }
282 
283         // Coroutine to manage video playback at start
284         private IEnumerator PlayStart()
285         {
286             VideoPlay();
287 
288             yield return new WaitForSeconds(0.01f);
289 
290             VideoStop();
291         }
292 
293         // Method to handle the play/pause button click
294         private void BtnPlayVideo()
295         {
296             if (videoIsPlaying)
297             {
298                 VideoPlay();
299             }
300             else
```

```
301             {
302                 VideoStop();
303             }
304             videoIsPlaying = !videoIsPlaying;
305         }
306 
307         // Method to pause the video
308         private void VideoStop()
309         {
310             videoPlayer.Pause();
311             btnPause.SetActive(true);
312             btnPlay.SetActive(false);
313         }
314 
315         // Method to play the video
316         private void VideoPlay()
317         {
318             videoPlayer.Play();
319             btnPause.SetActive(false);
320             btnPlay.SetActive(true);
321         }
322 
323         // Method to hide/show the video in full-screen
               mode
324         private void HideFullScreen(bool fullIsClicked,
               DeviceOrientation previousOrientation)
325         {
326             if (fullIsClicked == true)
327             {
328                 int rotationVideo = -90;
329 
330                 if (previousOrientation ==
                       DeviceOrientation.LandscapeRight)
331                 {
332                     rotationVideo = 90;
333                 }
334 
335                 float h =
                       Canvas.GetComponent<RectTransform>().rect.height;
336                 float l =
                       Canvas.GetComponent<RectTransform>().rect.width;
337 
338                 cinemaPlane.SetActive(true);
339                 scale = Math.Min(l / 108, h / 198);
340                 this.GetComponent<RectTransform>().SetParent(cinemaPl
                       false);
```

```
341                 this.GetComponent<RectTransform>().rotation
                        = Quaternion.Euler(0, 0,
                        rotationVideo);
342                 this.GetComponent<RectTransform>().anchorMin
                        = new Vector2(0.5f, 0.5f);
343                 this.GetComponent<RectTransform>().anchorMax
                        = new Vector2(0.5f, 0.5f);
344                 this.GetComponent<RectTransform>().localPosition
                        = new Vector3(0, 0, 0);
345                 this.GetComponent<RectTransform>().localScale
                        = new Vector3((scale / 3) - 0.1f,
                        (scale / 3) - 0.1f, (scale / 3) -
                        0.1f);
346                 btnFScreen.GetComponent<Image>().sprite
                        = spriteReduce;
347             }
348             else
349             {
350                 this.GetComponent<RectTransform>().SetParent(contentP
                        false);
351                 cinemaPlane.SetActive(false);
352
353                 if (indexMax != 0)
354                 {
355                     scale = (float)580 / 594;
356                     this.GetComponent<RectTransform>().sizeDelta
                            = new Vector2(580, 324 * scale);
357                     this.transform.SetSiblingIndex(indexVideo
                            + 1);
358                 }
359
360                 this.GetComponent<RectTransform>().anchorMin
                        = new Vector2(0f, 1f);
361                 this.GetComponent<RectTransform>().anchorMax
                        = new Vector2(0f, 1f);
362                 this.GetComponent<RectTransform>().rotation
                        = Quaternion.Euler(0, 0, 0);
363                 this.GetComponent<RectTransform>().localScale
                        = new Vector3(1, 1, 1);
364
365                 if (indexMax == 0)
366                 {
367                     this.GetComponent<RectTransform>().anchoredPositi
                            = new Vector3(320, -180, 0);
368                 }
```

```
369                 btnFScreen.GetComponent<Image>().sprite
                        = spriteFull;
370             }
371         }
372 
373         // Method to increase video playback speed
374         private void ChangeVelocityUp()
375         {
376             levelVelocity += 0.1f;
377             if (levelVelocity > 1.5f)
378             {
379                 levelVelocity = 1.5f;
380             }
381 
382             videoPlayer.playbackSpeed = levelVelocity;
383             string niceTime = string.Format(" {0:0.00}",
                    (float)levelVelocity);
384             txtVelocity.GetComponent<Text>().text =
                    niceTime;
385         }
386 
387         // Method to decrease video playback speed
388         private void ChangeVelocityDown()
389         {
390             levelVelocity -= 0.1f;
391             if (levelVelocity < 0.5f)
392             {
393                 levelVelocity = 0.5f;
394             }
395 
396             videoPlayer.playbackSpeed = levelVelocity;
397             string niceTime = string.Format(" {0:0.00}",
                    (float)levelVelocity);
398             txtVelocity.GetComponent<Text>().text =
                    niceTime;
399         }
400 
401         // Method to change the index of the video being
                played
402         public void ChangeIndexVideo()
403         {
404             indexVideo =
                    this.transform.parent.GetComponent<ManageToogles>().cu
405             ChangeVideoIndex();
406             this.transform.SetSiblingIndex(indexVideo +
                    1);
```

```
407                 btnFirstPlay.SetActive(true);
408                 videoIsPlaying = false;
409                 StartWhenUWant();
410             }
411         }
412 }
```

Listing C.8: ImageTracking.cs script - Allows one-to-one correspondence between traced image and corresponding prefab. The prefab can be of any type from a panel containing information to a 3D object

```
1
2  using System.Collections;
3  using System.Collections.Generic;
4  using UnityEngine;
5  using UnityEngine.XR;
6  using UnityEngine.XR.ARFoundation;
7  using UnityEngine.XR.ARSubsystems;
8
9  [RequireComponent(typeof(ARTrackedImageManager))]
10 public class ImageTracking: MonoBehaviour
11 {
12     [SerializeField]
13     private GameObject[] placeablePrefabs;
14
15     private Dictionary<string, GameObject>
          spawnedPrefabs = new Dictionary<string,
          GameObject>();
16     private ARTrackedImageManager trackedImageManager;
17
18     private void Awake()
19     {
20         trackedImageManager =
              FindObjectOfType<ARTrackedImageManager>();
21         foreach(GameObject prefab in placeablePrefabs)
22         {
23             GameObject newPrefab = Instantiate(prefab,
                  Vector3.zero, Quaternion.identity);
24
25             newPrefab.name = prefab.name;
26             // personalized transform of GameObject
27             if (newPrefab.name == "HBim")
28             {
29
30                 newPrefab.transform.localScale = new
                      Vector3(0.02f, 0.02f, 0.02f);
31                 newPrefab.transform.localRotation =
                      Quaternion.Euler(-90, 0, 90);
```

```
32                  //newPrefab.transform.localPosition =
                        Quaternion.Euler(0, 0, 1);
33              }
34              else if(newPrefab.name == "Gio")
35              {
36                  newPrefab.transform.localScale = new
                        Vector3(0.05f, 0.05f, 0.05f);
37              }
38              spawnedPrefabs.Add(prefab.name, newPrefab);
39              spawnedPrefabs[prefab.name].SetActive(false);
40          }
41      }
42
43      private void OnEnable()
44      {
45          trackedImageManager.trackedImagesChanged +=
                ImageChanged;
46      }
47
48      private void OnDisable()
49      {
50          trackedImageManager.trackedImagesChanged -=
                ImageChanged;
51      }
52
53      private void ImageChanged
            (ARTrackedImagesChangedEventArgs eventArgs)
54      {
55          foreach(ARTrackedImage trackedImage in
                eventArgs.added)
56          {
57              UpdateImage(trackedImage);
58          }
59
60          foreach (ARTrackedImage trackedImage in
                eventArgs.updated)
61          {
62              UpdateImage(trackedImage);
63          }
64
65          foreach (ARTrackedImage trackedImage in
                eventArgs.removed)
66          {
67              spawnedPrefabs[trackedImage.name].SetActive(false);
68          }
69      }
```

```
70
71      private void UpdateImage(ARTrackedImage trackedImage)
72      {
73          // move GameObject following image position
74          string name = trackedImage.referenceImage.name;
75          Vector3 position =
               trackedImage.transform.position;
76          GameObject prefab = spawnedPrefabs[name];
77          prefab.transform.position = position;
78          prefab.SetActive(true);
79
80          foreach(GameObject go in spawnedPrefabs.Values)
81          {
82              if(go.name != name)
83              {
84                  go.SetActive(false);
85              }
86
87          }
88
89          if (trackedImage.trackingState ==
               TrackingState.None)
90          {
91              foreach(GameObject go in
                   spawnedPrefabs.Values)
92              {
93                  go.SetActive(false);
94              }
95          }
96
97
98      }
99  }
```

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