VR and the Perception of the Space: A Sensorial Labyrinth Inspired by Giambattista Piranesi's *Carceri D'Invenzione*

Simona Calvagna, Federica Grasso, and Cettina Santagati

Abstract The Virtual Reality project called *Piranesi "beyond the real"* aims to help the understanding of the series of etchings *Carceri d'invenzione* (*Prisons of invention*) by Giovanni Battista Piranesi, exhibited in the Museum of Representation of DICAR (University of Catania), participating in the strategies of co-creation of cultural content implemented by the museum. The research begins with a careful investigation of the etchings, which reveals immense spaces where bridges, towers, and stairs seem to follow each other endlessly. The only things in between are wooden beams, ropes or instruments of torture, used by surreal giant men in the foreground or "human ants" in the distance. The spaces that inspire this project are intended as the dream of a young man because of the fever or the genius of his black mind. The virtual labyrinth is a journey designed from the sensations of the Prisons, an immersive experience in completely new environments. Anxiety, disorientation, and illusion are the focus, the goal is the awareness of them. Two levels, two different perceptions of space: the first is an immense and dark underground labyrinth, which sinks vertically towards infinity with flights of stairs, high walls, suspended or recessed platforms; the second is an open space, which extends towards the horizontal infinity, extremely bright. it is a conceptual labyrinth, which can be crossed in many ways, with endless exits, and an end. That is the place where the visitor can complete the ascent being aware of the places he crossed. The study of spatiality was also conducted through the aid of a 1:200 scale physical model, which allowed us to verify the project hypotheses.

Keywords Virtual reality · Labyrinth · Sensorial · Piranesi · Carceri d'invenzione · Museum storytelling

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1 Introduction

The project intends to recreate in VR a *Piranesian space* in a contemporary key. It was born with the intention of increasing the understanding of Giambattista Piranesi's exhibition at Mura, Museum of Representation of the University of Catania. Virtual Reality (VR) has been chosen as a better method to achieve that purpose. Museums, in fact, are increasingly integrating VR in their exhibit because of the immersive experience they offer, which leads to a deeper comprehension of it.

The project has been developed with the support of the two laboratories of MuRa: R^3D (Laboratory of Survey, Representation and Digital Reconstruction) and SPrA (Instruments for the Architectural Project).[1] In this context, the project has been realized in both virtual and real way, as a VR project to be immersively experienced by using the visor and as a physical model to be seen from the exterior to better understanding the totality of the spaces created.

After the careful study and analysis of the life and works of Giovanni Battista Piranesi, the attention was focused on his revolutionary idea of 'space', so important in all the works he made. In particular, the study of the Prisons space was deeply analyzed through a better study of the atmospheres and figurative characters that Piranesi was able to transmit through the masterful control of the instruments of representation.

The first question made was: how could the intentions of Piranesi expressed inside the *Carceri d'invenzione* be better appreciated? And so, how can the visitor understand what inspired Piranesi in making those etchings?

The study of the *Carceri d'invenzione* led to identify the attributes of what the critics call a "Piranesian space": an immense labyrinthic space, where silence and darkness face chaos and light, where interior and exterior are strictly related, in a sequence of contrasts that lead to paradox. The visitor of that space is inexorably overcome by anxiety and needs to find a way out by exploring and, consequently, discovering the hidden from the evident (Fig. 1).

The space projected starts from these concepts that identify a *Piranesian space,* creating a new one in a contemporary vision: it is dominated by contrasts, sometimes defined by light over darkness and sometimes by darkness over light.

Space has been conceived as a virtual expansion of the museum and consists of two parts on two different and separate levels. It is a labyrinth, but no longer a classic one, defined by high walls, intersections and blind spots, but an infinite labyrinth. It becomes a maze, conceived as a desert, without landmarks and without corridors or tunnels. It is precisely the absence of these elements that makes it a maze, in which the search for a way out from an environment that seems always the same goes on forever.

[1] This project was realized as graduation thesis of Federica Grasso in Building Engineering and Architectural Construction at University of Catania, titled "Piranesi oltre il reale. Progetto di un labirinto sensoriale virtuale ispirato alle *Carceri d'invenzione*". The professors Simona Calvagna and Cettina Santagati were the thesis' mentors.

Disorientation and anxiety are the feelings that overwhelm the visitor while walking through the space. The visitor will start from the downer part and then arrive, through a journey of ascent and discovery of the meanders of a real underground labyrinth, to the top, where the labyrinth becomes abstract.

The end of the path marks the culmination of the ascent, where the visitor gets to the highest point, from which he can see the route made and become aware of how he got there and of the spaces he passed through. It is so a mental labyrinth, a psychological maze from where is impossible to escape because is nothing else than the world we are living in and where we are trapped in, or rather, our perception of it. After walking this path inside of the *Piranesian space*, the person who visits understands that he must find a way to live in it instead of a way out. It is a mental prison, that here is represented by a sensorial labyrinth whilst in *Carceri d'invenzione* by real prisons. The main aim that Piranesi wants to reach through this work is perhaps to lead the observer to understand this concept, to understand that the *Carceri* are nothing else than a reflection of real life.

The chapter is structured as follows: it begins with the description of the state of the art, dealing with VR today, virtual museums and the meaning of sensorial spaces in the project of architecture; then, objectives and methodology of the project will be shown, before to move on the case study, i.e. the Museum of Representation (MuRa), Giambattista Piranesi and the virtual sensorial labyrinth; and, finally, the conclusions will be drawn.

2 Background

2.1 VR Experiences and Virtual Museums

Virtual Reality was born with the 'experience theater' and the machine *Sensorama*, created by Morton Heilig in 1962, with the purpose to immerge the spectator into the movie by putting him inside of the action that was going on the screen through the senses of sight, hear, smell and tact. After that, the term began to be used to indicate the simulation of spaces or realistic situations where the user was invited to interact with the scene trough visors, data gloves and joysticks (Fig. 2).[2]

The concepts on which VR is based are tree: immersivity, interaction and connection of the user with the ambient. These features define the level of perception in virtual reality and allow to classify a space as believable.

VR headsets now in use have been developed from different companies, in detail the most used are *HTC Vive Pro, Oculus Rift S, Samsung New Gear VR,*

[2]The first visor, called *Damocles' sword*, was invented in 1968 by Ivan Sutherland and Bob Sproull and it was so heavy that it required a support structure. However, the visor that opened the era of virtual reality has been the *Aspen Movie Map*, a software invented by MIT in 1977 that let people walk virtually through the streets of Aspen, Colorado.

Fig. 1 Giovanni Battista Piranesi, Carceri d'invenzione, second edition, 1760, plate XIV. *Credits* Princeton University Art Museum

Google Daydream and *PlayStation VR*. There are also visors that can be used with smartphones, such as the *Google Cardboard*.

A visor need to satisfy few parameters to be used for VR, it needs: a field of view between 100° and 110°; a frame rate between 60 and 120 fps (frame per second); a gyroscope, an accelerometer and a magnetometer, in order to have a head tracking between 50 and 60 ms; a professional audio system; a system of eye tracking that allows to read the movement of the eye though infrared pointers.

Virtual Reality is mostly used for video games, although there are many fields of application. Its use is growing more and more also in the field of cultural heritage because it allows people to visit expositions and archeological sites in a more interactive way. Despite this, lots of museums managers limit the use of VR due to the inclination to alienate the visitor from the world. The most interesting applications in this field are the virtual visit to the digital reconstruction of monuments in their original state, or of sites that are inaccessible or hard to reach.

There are many software optimized to make VR projects. They are created to develop video games, but it is possible to use them also in the architecture field. The two most common open source software are *Unity* by *Unity Technologies* and *Unreal Engine* by *Epic Games*. Additionally, there are software created specifically

Fig. 2 **A** Sensorama, the first virtual reality machine; **B** Damocle's sword, the first virtual reality system with headset (so heavy it had to be supported by a structure); **C** Virtuality headset and glove. *Credits* A, B & C: Bianchini, Riccardo, "Quando i musei diventarono virtuali" in *Inexhibit*, 10/06/2016

for architecture visualization and design, e.g. *Eyecad VR* by *Digital Atoms. Unreal Engine* is the software used for the present project.

The concept of 'Museum' has changed substantially over time: from the traditional museum, seen as the planning of exhibitions of important works of art and objects inside a building, to the museum in a broader sense, seen as "a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment". (ICOM 2007) This definition is not considered any more appropriate to the contemporary museum. For this reason, during the ICOM's 25th General Conference, held in Kyoto (Japan) from 1 to 7 September 2019, a new definition has been proposed. This new definition hasn't been approved and it's still being discussed to ensure that it adapts as much as possible to the museum as it is today.

The idea of 'virtual museum' was born around the 1980s, when computers began to be commonly used. Museums didn't change many since the nineteenth century, they were no longer suitable for a society that developed so much. There was the need

Fig. 3 Digital installation at MuRa. *Credits* Museum of Representation

to adapt the museum reality to the new people's way to live. Information technology and virtual resources were the key to promote the culture inside museums (Figs. 3 and 4).

Initially 'digital museum' were created with the objective of speeding up the process of archiving, inventory and administration. Many museums also created their own CD-ROM with their virtual clone with the dual purpose of digital archiving and of better fruition of the works contained in the museum. In the following decade the Internet rapidly expanded, giving to museums the possibility to share their digital parts with the rest of the world. In the meantime, many museums started to have virtual parts, where the visitor could have an immersive experience, and sometimes a dedicated computer room for digital consulting, with the purpose of deepening the works or better understand some aspects of them.

The virtual museum has enormous potential: along with the traditional methods, it can help to restore importance and visibility to the museum's institution, creating "a dimension that allows us to experiment on the entire cultural heritage with cultural experiences and social interaction that are impossible in real-world institutions." (Galluzzi 2010).

Fig. 4 Virtual exploring of a 3D model from photogrammetric survey at MuRa. *Credits* Museum of Representation

2.2 What Is a Sensorial Space? How to Project It?

"Quality architecture to me is when a building manages to move me. […] One word for it is atmosphere. […] I enter a building, see a room, and—in the fraction of a second—have this feeling about it." (Zumthor 2006).

Atmosphere stays in the quality of the space, in the first emotional perception, in the man-things relationship, in the intensity and density of the space and in the relation between the objects or the materials inside of it. Each building gives a unique experiential perception, it generates its own sensations that will not ever be the same in another space. Walls, surfaces, columns, pillars, changing materials are defined by the tension between them. "Space is the essential mean of architecture. It is many things simultaneously: the voids and space around the architecture, the vastness of the landscape and the city, the intergalactic space of the universe. Space is something intrinsic and relational." (Holl 2004).

People, walking through the architecture, modify the space and have a perception of it that depends on those changes. For this reason, everyone can feel the atmosphere of a space in his personal way. It becomes "expression of moods in lived situations,

which occur in habitual human action; guided by a poetic objective." (Pérez 2018). Furthermore, memories bind the person to a specific place, and it can influence the perception of other similar spaces, making them associate the feeling of the past place to the recent seen one.

The movement itself generate a connection between the guest and the architecture. The person moves inside the architecture, discovering its parts, its materials, modifying the plans that delimit the space during the movement. This process is called *parallax*, i.e. the movement of the object seen due to the movement of the observer. "Vertical or oblique movements through urban space multiply out experiences." (Holl 2004). Light also is part of this process: light generates movement and movement produces the perception of the space. "Architecture manifests itself in perception" says Holl (2004). Light, time, material and detail merge, becoming a 'whole'. They can't be perceived separately anymore.

There are 9 points that characterize sensoriality, emotional expressions and so the atmosphere of a building, according to the swiss architect Peter Zumthor, those are: the 'materials' that emanate their own quality from their relation; the 'sound', the noise of that site, the silence from where architecture is created; the 'body' of the building that you can touch; the 'temperature' of the building; the 'objects' that characterize the life and the presence of the residents; the relation 'between composure and seduction' in wandering within spaces; the 'tension between interior and exterior'; the 'levels of intimacy' that result in distance and proximity, in weight, volume of objects, in the relationship between their dimensions within the space; the 'light' that generates from darkness, defining the spaces (Fig. 5).

The project of a sensorial space starts from these principles, taking them as a reference in relation to the characteristics of the Piranesian spaces.

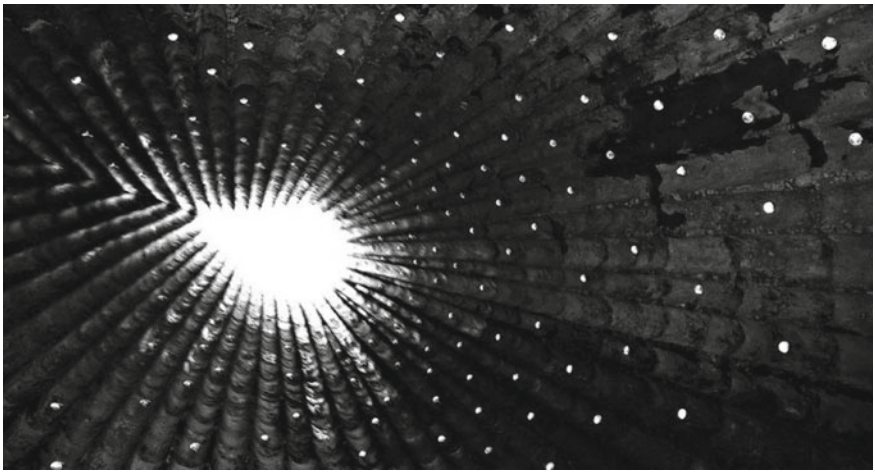

Fig. 5 Bruder Klaus Chapel, Peter Zumthor, Mechernich, Germany, 2007. http://sacrark.altervista.org/peter-zumthor-bruder-klaus-kapelle/

3 State of the Art

In museum context Virtual Reality is starting to become very used. In the following part are showed significant examples.

The Hunterian Museum at the University of Glasgow (UGLA) in 2017 started a 3-year research and innovation project, called *EMOTIVE Hunterian Museum digital storytelling about the Antonine Wall*. This project aims to use emotional storytelling, through the EMOTIVE tools, to change the traditional experience of museums and heritage sites. The EMOTIVE project offers different tools to create experiences for on-site or remote visitors, such as 'Interactive storytelling experiences for mobile devices' (an app for smartphones that guides the visitors around the museum though immersive narratives), 'Bring your experiences online' (an editor that allows to easily create a 360° virtual space from photographs and share it on the EMOTIVE's Web Experiencing System in order to be experienced off-site), and 'Bring objects to life' (the combination of a 3D printer that cast historical artefacts' replicas and the EMOTIVE's Mixed Reality Plugin for Unity that brings back the objects to their original glory using a VR headset).

Immersive VR/AR Museum Guide for the Miocene Site of Stetten, Austria is a project developed in 2017 for the Theme Park 'Fossilien Welt'. A 3D reconstruction in the paleontological era had already been made in 2014 for an area of approximately 50 km^2 of the terrain of the Korneuburg basin. The new objective is to narrate the history of the ocean and its inhabitants using animated 360° scenes. In this context, an application was created to let the visitors download it on their smartphones and have a complete guide of the site, optionally seen in an immersive 3D vision with the use of a lightweight VR headset specially developed for the purpose.

Another relevant example is *Ullastret, 250 B.C. a virtual reconstruction of an Iron Age Town.* The project consist in a digital storytelling experience based on a 3D model of the iron-age archaeological site of Ullastret in Empordà, Catalonia, developed in two different applications: an audio-visual for an on-site immersive room that consent exploring the ancient towns through a six-minute overview of the digital model and an adaptation for VR headsets, that generates more complete and realistic experiences because of the total immersion in the virtual space.

The project *Piranesi* "*oltre il reale*" forms part of this scenario and differs from it at the same time. It is a sensorial labyrinth that can be walked in an immersive experience using a VR headset. It is a path, a process of discovering through contrasts from a dark infinite vertical labyrinth to a bright infinite horizontal one. The visitor can feel the sensations of the Piranesian space during a process of discovering of the spaces, while his awareness of it grows. It was born from a meticulous research on Piranesi's *Carceri d'invenzione* and the consecutive definition of a Piranesian space and of its characteristics. Thanks to this experience the visitors of the Museum of Representation can relate the physical exhibit of the series of *Carceri d'invenzione* and the virtual space, thought as an expansion of the museum where itself becomes the object of the exhibition.

4 Method

The project aims to allow the museum visitors to experience a Piranesian space from the inside. It enables them to better understand the sensations that Piranesi wanted to express with the series of etching *Carceri d'invenzione.*

As seen in the previous paragraph it is necessary to change the concept of museum with a new one, that integrate new technologies in the traditional visit of the museum, in order to be more appreciated by today's audience and encourage the interaction. So, creating a virtual walkthrough inside a Piranesian space was the best way to reach the purpose of the project. An immersive experience in this sensorial labyrinth would have let the visitor to feel the emotions that designed that space.

The project has passed through many phases:

- An extensive research on Giovanni Battista Piranesi and his work, focusing on Carceri d'invenzione.
- A process of extracting concepts and defining what a piranesian space is, ending with a cloud of words that contains them all.
- The ideation of a physic space from these concepts and its continuous transformation.
- The built of this space in 3D in both physical and digital way, creating a maquette and a 3D digital model on Rhinoceros 6.
- Creation of the virtual experience by importing the Rhino model into Unreal Engine 4, using the tool Unreal Datasmith available for Unreal Studio: setting the light and materials effects; creating a virtual walkthrough; setting interactions via blueprints tools.
- Creation of the virtual reality workstation inside of the Museum of Representation.
- Evaluation test of the prototype.
- Making of the final maquette to be part of the exposition at the museum (Fig. 6).

5 Case Study

5.1 Museo Della Rappresentazione

Museum of Representation (MuRa), managed by the Department of Civil Engineering and Architecture (DICAR), is one of the 21 museum that constitute the University of Catania's Museum System (SiMuA). It is in via Etnea, one of the most important streets in Catania, inside of Villa Zingali Tetto, the symbol of the advent of Art Nouveau in Catania. The villa was commissioned by the lawyer Paolo Zingali Tetto to the architect and engineer Paolo Lanzerotti and realized in 1926. The lawyer lived in there until his death, in 1969, and bequeathed it to the University of Catania. Since 1972, the University used the villa in very different ways, from seat of the Library and Documentation Center (CBD) to 'Casa della Città', after the restoration

Fig. 6 Exposition of the maquette during the visits at MuRa. *Credits* Simona Calvagna

work in 1999. Then it was closed from 2012 and, thanks to the establishment of SiMuA, finally opened as 'Museo della Rappresentazione' in 2016 (Fig. 7).

Museum of Representation aims to strengthen the research and teaching activities of DICAR in the field of architecture and preservation and protection of heritage documents owned by the Department. With this purpose were created the R^3D Lab and the sPrA to promote internal research and teaching experiences, as well as experiences with external institutions such as schools, Municipalities, Superintendence, private bodies and professional offices, within local cultural heritage projects.

The heritage managed by the museum mainly consists of two collections: the Piranesi's fund, that collects more than a thousand etchings of the eighteenth century, and the Fichera's fund, formed by about 1600 heliographic copies and original drawings made with different techniques. In addition to these, there are engravings and drawings by De Vico, De Rossi, Savorelli, Pannini e Camporesi.

Fig. 7 Villa Zingali Tetto, Catania, Giardino d'inverno. *Credits* Giuseppe Tuttobene

The permanent exposition also includes the work of the Laboratories: a digital exposition of 3D reconstruction, photogrammetric and laser scanner surveys realized during educational or research activities that can eventually be seen with a VR headset by scanning the QR code on the smartphones; and the exposition of the more representative *maquettes* (physical models) realized by the students during lessons or workshop.

5.2 Piranesi and Piranesian Spaces

To better understand the project, it is necessary to have some knowledge of Giovanni Battista Piranesi and the spaces he created in his works.

Piranesi was an engraver, architect and architectural theorist that lived his life mostly in Rome. He was born in Venice in 1720 and, after a period practicing in engineering and architecture office, decided to move to Rome to learn the art of engraving. He was incredibly fascinated by the Ancient Rome, he spent days and nights observing every single detail and drawing them. The most part of the work of his life have Rome as protagonist. This love he felt for the ruins, for the magnificence of another era that was going to be forgotten in some time, for the immense buildings he imagined from the remains started a process of creation of spaces.

This process gave birth to the series of engravings *Carceri d'invenzione.* They took shape from this interior world, like a dream. The first version, published in 1745, was evanescent, defined by soft lines that ended in clouds of white smoke. It was not already defined; it was an idea and he wanted to visualize it. The second version, reworked and published in 1760, showed the spaces in all their parts. The lines were darker, and it gave materiality to the drawing. Towers, bridges, arches, stairs, ropes and torture instruments and again in an infinite loop. Infinite spaces, out of scale, accentuated contrasts, a more defined symbology are the characteristics of the *Carceri d'invenzione.*

This is for sure the most known and interiorized work he did in his life, as well as the several etchings of the series *Vedute di Roma.* He dedicated his life to represent the city of Rome as it was in eighteenth century, working constantly until his death in 1778. His son, Francesco, continued the work of his father and preserved the copper plates, that are now located in the National Institute of Graphics in Rome.

From the analysis of the *Carceri d'invenzione* and of the opinions of the critics expressed over time, we can define what a Piranesian space is (Fig. 8). It is characterized by exaggerated proportions of space, illusory perspective effects, tendency to infinity, uncertainties on the boundaries between external and internal environments, pronounced effects of contrast light-shadow, elements that break the view, the labyrinthine spaces.

It is an immense sequence of spaces expressing a complex vision of the world, affected by the dreams dealing with an ancient period and the reality of the world of the eighteenth century. It is a labyrinth for the mind, where the observer lose himself while trying to find a connection, a way out that does not exist. It represents the real

Fig. 8 Word cloud of the Piranesian space concepts. *Credits* Federica Grasso

world where we are constricted, the society that rapidly evolves inside of spaces that no longer belong to the people. The sensation is of being prisoners of this spaces, prisoners of life. The only way to stop roaming is to become aware that place is just a representation of the real world and we cannot escape from it, we have just to learn how to live in it.

The labyrinth then is the most appropriate instrument to represent the Piranesian space. It is a very remote origins' symbol, appeared for the first time in the Ancient Greek. Its meaning changed over time: from a path to a center that was difficult for his deep meaning and not for his complexity in shape, to a very intricate path where the difficulty stayed in finding the way out because of dead ends or multiple pathways. In English this difference is clearly expressed in the term's 'labyrinth', for the first meaning, and 'maze', for the second.

The interpretation of the labyrinth has always been twofold, from a physical place of bewilderment and perdition to a mental place in where to face fears to find oneself. With Piranesi this duplicity is combined in the anguishing representation of the places within the *Carceri d'invenzione*, maybe the first example of three-dimensional mazes.

The man, within the labyrinth, is called to understand his role because only through the attainment of such knowledge he can live there without being one of those sketchy figures wandering in the background. Perhaps it is losing orientation that he can find the exit.

The labyrinth becomes a journey: a psychological journey into oneself and a physical journey into life. The intricate pathways, defined by the difficulties of life, lead to the center of the consciousness, where the person must 'kill the beast' in order to rebirth and exit. The traveler finds himself in an infinite cycle of spaces in succession, a nightmare with boundless, infinite dimensions. Time slows down, until it stops, and gives us the view of a moment. A representation so dynamic, however, to make it appear real.

The human figure appears small in comparison to the spaces, sometimes so small as to look like an ant. The man loses his way inside the prisons, roams, lose himself and then tries to find himself again. The discovery of oneself takes place in the acceptance of disorder and of the contradiction of things, in the criticism of the ordinary and in the discovery of the hidden.

6 The Project: The Virtual Sensorial Labyrinth

Piranesi "oltre il reale" starts from the concepts described in the previous paragraph to create a new virtual space. It is a virtual prison of mind, a place where the visitors can live the Piranesian space, instead of just observing it. VR allows to approach differently to the exposition: walk inside of it, in this case.

The Piranesian space can be considered an infinite place, inside of which the person loses himself not only in the physical sense, but above all in the mental sense. The discovery only takes place after the acceptance of the disorder and the contradiction of the 'goods', it lays in the criticism of the ordinary and in the discovery of the hidden. It is with the immersion in a sensory experience that allows such self-discovery. It's necessary to be prisoners of this infinite space and to become aware of it to finally live without the constant need to find a way out.

It is a sensorial labyrinth, created from feelings to let the people feel them through the space. It is a path of self-knowledge where different types of contrast are experienced: from the emptiness to the excess of forms, from the sizes out of scale to the smallness of the man, from the psychological upheaval to the awareness of reality as it is, from the obvious to the hidden, from chaos to rule, from darkness to light (Fig. 9).

The experience, introduced into the new exhibition at the noble floor of MuRa, begins when the visit at the Piranesi's section ends. The last room of Piranesi's exhibition is dedicated to multimedia contents, the VR experience is situated over there. This experience is configured as a virtual extension of the museum dedicated exclusively to the famous series of engravings. The museum itself becomes the exhibit. By wearing the viewer, the connecting door between the museum's multimedia room and the virtual exhibition it's conceptually passed through. The visitor falls into the Piranesian space and the course to discovery and self-knowledge begins.

The space was created from the breakdown of a roman labyrinth (Fig. 10). The breakdown generated two contrasting levels: the lower one tends to vertical infinity, it is an internal space, underground, composed by horizontal plans connected by flights of stairs accompanied by walls. The visitor is forced down the labyrinth, where he can feel the disorientation, the anxiety, the vertigo and experiment darkness and silence, until the last platform. That is the connection place with the upper level. This level is exterior, bright and chaotic, composed by an infinite expanse of parallelepipeds that follow the original path of the roman labyrinth. The own concept of labyrinth had a breakdown in here, becoming a maze with infinite ways of passing through. No more walls, just white concrete blocks of different heights (Figs. 11 and 12).

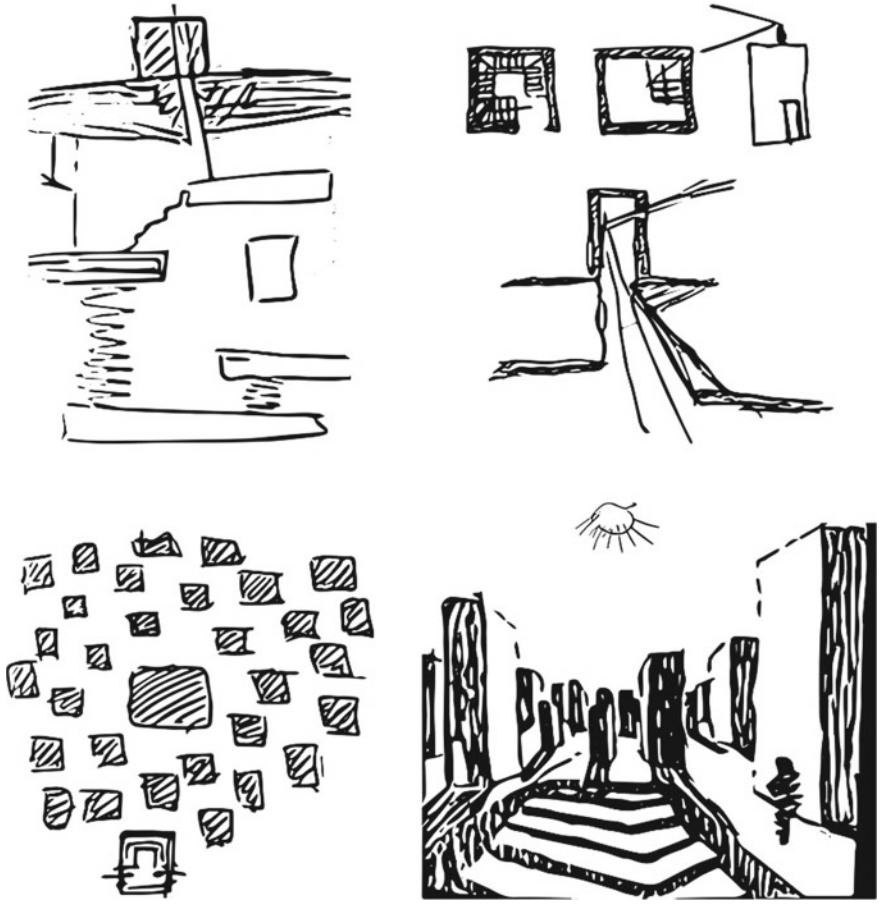

Fig. 9 Sketches made during the making process of the project. *Credits* Sketches by Federica Grasso

The connections between the two levels is the light. From the upper level light goes down passing through skylights; the rays go down, defining the spaces by the light rays on the darkness.

The experience passes through these spaces, gradually exploring and revealing their characteristic and the contrasts: from out of scale to human proportions, from darkness to light, from silence to chaos, until arriving to the final block (Figs. 13 and 14).

This block, conceived as a third level, embodies the characteristics of both upper and lower level in a last element, where awareness is reached. It is at the exit of the original labyrinth path, that correspond exactly with the starting point of the experience and marks the end of the psychological cycle. It is a space like those seen before: on the outside it seems a big white concrete block, on the inside it

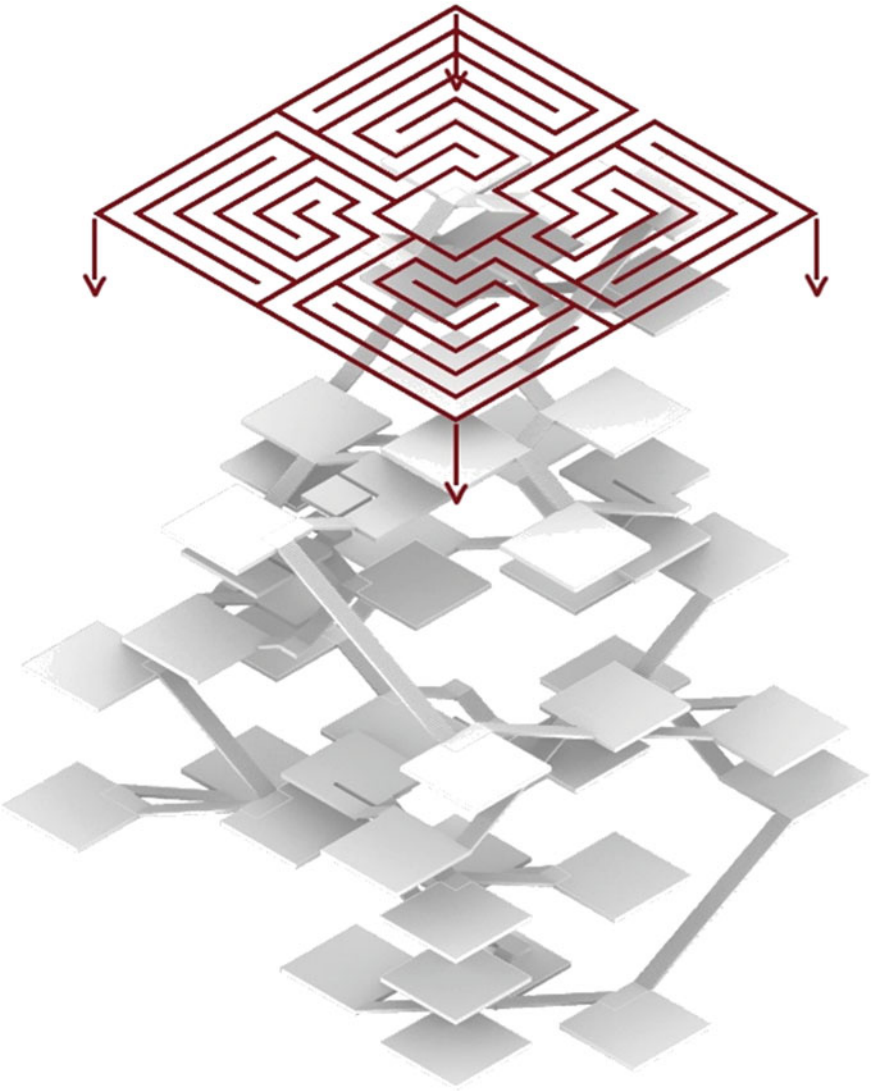

Fig. 10 Scheme of the breakdown for the lower level. *Credits* Federica Grasso

takes up the platform-stairs composition but, this time, human-sized. The feelings of bewilderment and anxiety disappear, now the visitor is aware of the spaces he crossed. The sequence of stairs leads directly to the last platform, to the roof height, opening the view to the newly crossed maze. This is the moment in which the visitor realizes that everything he has gone through is nothing but a reflection of the Piranesi's *Carceri d'invenzione* and of its feelings and concepts. It happens thanks to the anamorphosis of the Plate XIV from the second version of *Carceri* applied to the floor (Fig. 15).

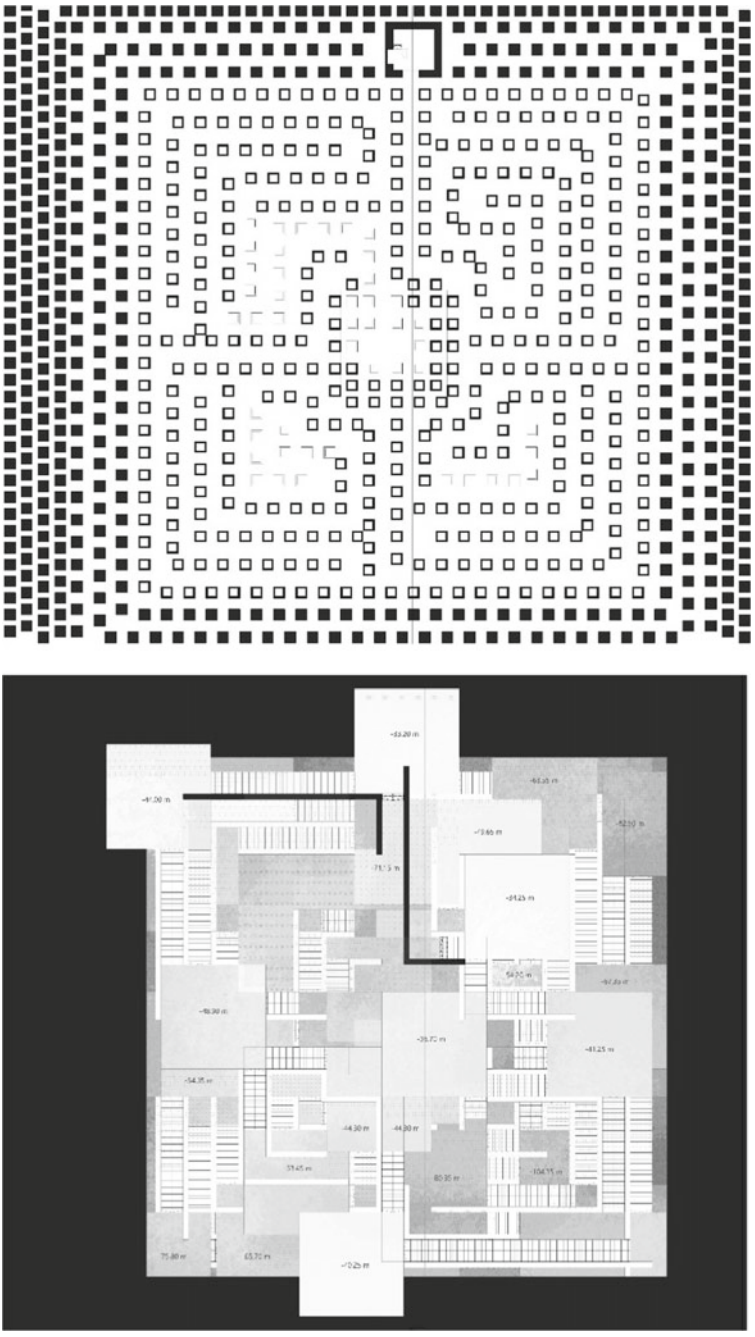

Fig. 11 Floor +1.00 m (Up). Floor −33.00 m (Down). *Credits* Federica Grasso

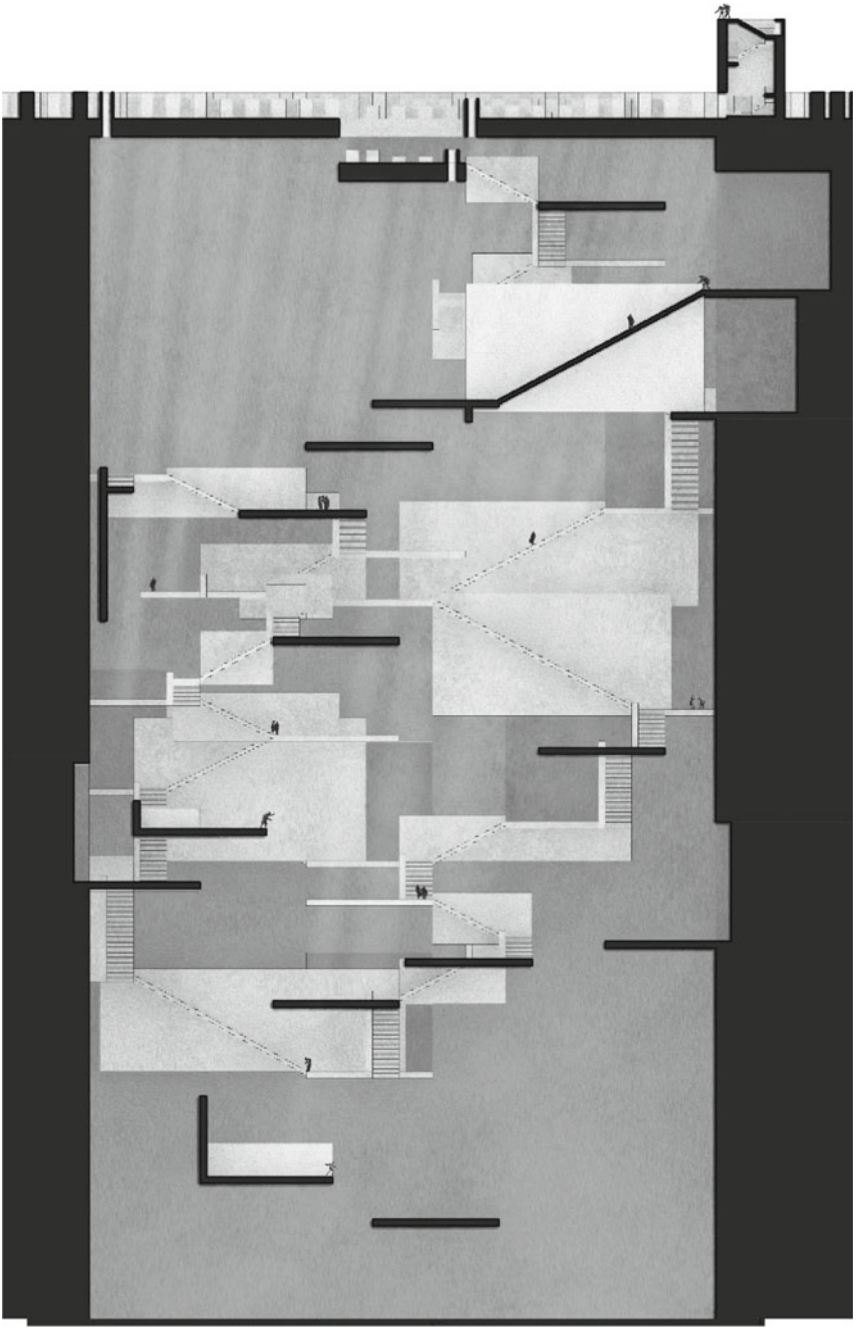

Fig. 12 Vertical section of the Piranesian space. *Credits* Federica Grasso

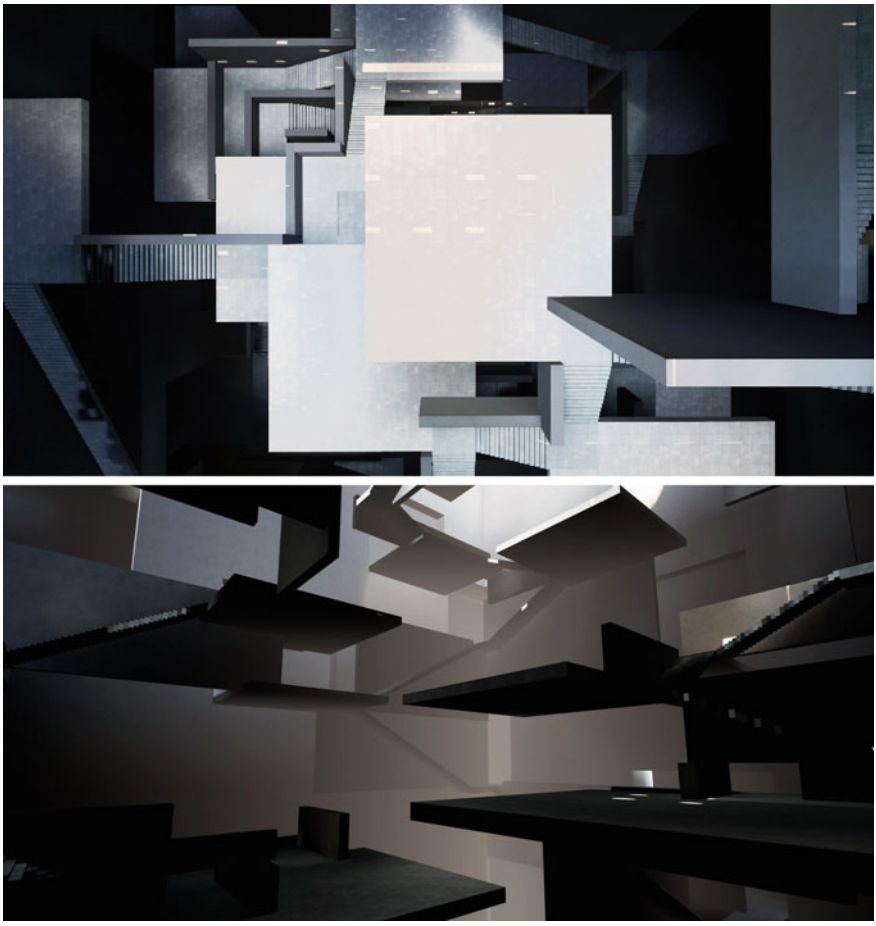

Fig. 13 Renders of the Piranesian space Piranesi "oltre il reale". A virtual sensorial labyrinth inspired by Giambattista Piranesi's carceri d'invenzione. *Credits* Render by Federica Grasso

The project was realized using Rhinoceros for the 3D model and Unreal Engine 4 for the optimization of light effects and materials and to make the experience explorable in VR. A physical model was also created to help the creation of the spaces in a 1:200 scale. The model was then transformed to the final definitive by printing in 3D the upper level and by using a CNC milling machine to cut the valchromat and the metal for the lower level.

The prototype has been tested many times and the results of the evaluation tests are very positive, evidencing the effectiveness of the project on the understanding of the Piranesian space and the feelings expressed in it.

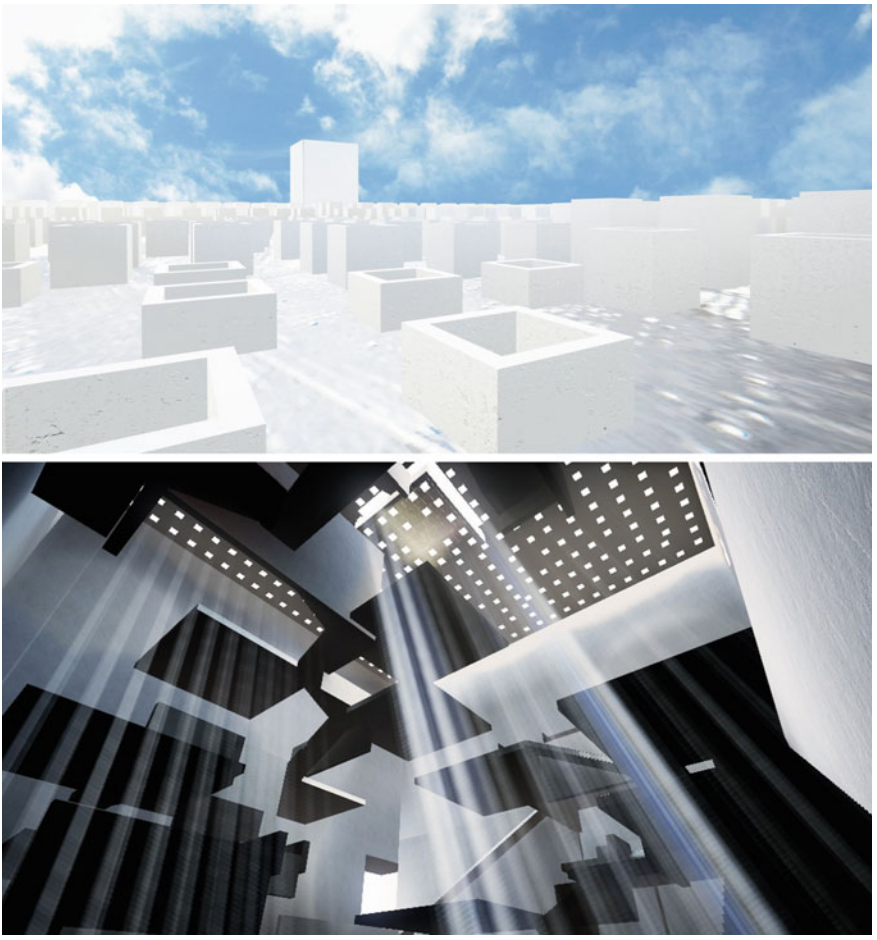

Fig. 14 Render of the Piranesian space Piranesi "oltre il reale". A virtual sensorial labyrinth inspired by Giambattista Piranesi's carceri d'invenzione. *Credits* Render by Federica Grasso

7 Conclusions

In this chapter we talked about Virtual Reality in museums, sensoriality and the process by which to create a virtual sensorial labyrinth.

The project responds positively to the identified needs: thanks to the VR experience of the project *Piranesi "oltre il reale",* the series of etchings can be better appreciated. By trying the experience, the visitor finds itself inside of a space created from the feelings of the *Carceri d'invenzione*, inside of a Piranesian space. This means that the visitor can experiment it from the inside, he can be immersed in that space, feel it and understanding it, instead of just looking and observing the plates of the series from the outside.

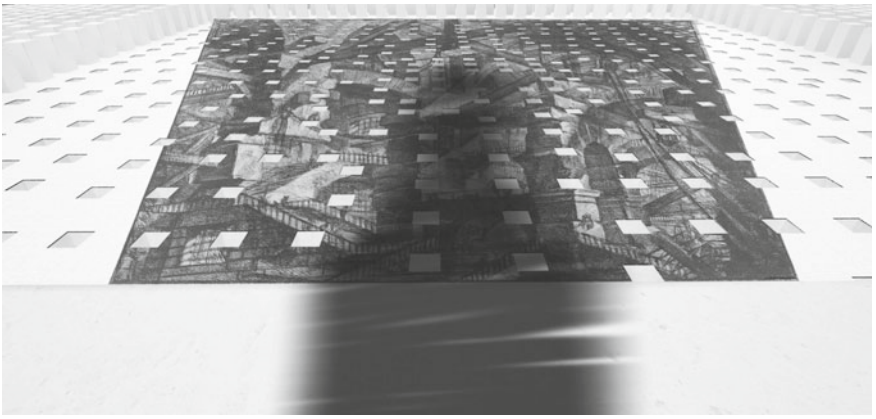

Fig. 15 Anamorphosis. view from the top of the final block. *Credits* Render by Federica Grasso

New virtual technologies, specifically Virtual Reality, are certainly a valuable tool for increasing the interest of visitors in the works of museums. The understanding of the works is also improved by virtual experiences, as the evaluation tests shows.

The project, currently inserted in a temporary exhibition on labyrinths at MuRa, will be integrated in the permanent one with the new set-up of the museum. The workstation will be located near the room dedicated to the series of etchings *Carceri d'invenzione*, in order to have the complete experience by observing and analyzing the etchings and then by living a Piranesian space in an immersive experience with the VR headset.

In the future the VR experience will be improved by creating a Serious Game that will allow people to interact with info panels or with drawn characters of the series and to play little games to help the discovery process.

Piranesi "oltre il reale" it's strictly connected to the *Carceri d'invenzione* series and it's not linked to one place. It is a virtual extension of the Piranesi exhibition; it has been created for MuRa but could be moved to others Piranesi's expositions if requested in order to give a different perception of the spaces represented in the series of etchings.

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