# Retro-Planning: A Time Machine for Cultural Heritage The Urban Gate S. Leonardo – Barletta (BAT)

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**Abstract.** The aim of this paper is to test the possibility of carrying out a backward design process, based on historical and iconographic data, to reconstruct an incomplete or destroyed heritage asset. By applying retro- planning, a reverse design process based on historical data, the gool is to restore the cultural asset studied to its original form, relocating it digitally, in the environment in which it stood when it was conceived by its designer. The technique was applied to the S. Leonardo gate in Barletta (BAT), which no longer exists today, but of which some artefacts are preserved. At the end of the reverse design, with digital modelling, it is possible to relocate the volumes of the architectural asset in the timeline to be passed on to future generations so that it will not be forgotten.

At the basis of the process, in addition to historical and iconographic research, it is necessary to investigate the construction techniques and materials in use at the time of the architectural asset to be redesigned, which is fundamental in order to create a model of the work as close as possible to the original. As will be seen, the expanded knowledge of those approaching this reconstruction process plays an important role, which most often starts with a few photographs and historical data that are not very representative of the real architectural form. For this reason, the intuitions of the operator are important in filling in the missing elements of the reconstruction process. The procedure has as its goal the representation of the cultural asset, elaborating in the drawings of the Mongiana representation the aspects proper to architectural speech in order to construct the idea initially elaborated by the creator of the work.

**Keywords:** Architecture · Retro - planning · Heritage

## 1 Introduction

Historical building heritage, in many aspects, is to be understood as a legacy of great value and necessarily to be protected, documented, studied and passed on. This represents a memory of the past of great importance, to be preserved in its place, recovering it for what it represented when it was created. The reading and knowledge of this building heritage that has been handed down to us or that has not come down to us because it has

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been lost or unfinished, passes through the understanding of the original design intention, to be elaborated and generate the digital representation of the forms and volumes that represent it. Only by understanding the original idea of the designer, the construction technique and the materials in use at the time when the Cultural Heritage was conceived, will it be possible with the digital technique to represent the real design idea of the factory studied.

The goal of the paper is to apply retrospective design for the virtual reconstruction of the lost architectural heritage, in order to allow a complete understanding of the analysed architecture. This technique has already been successfully applied for the reconstruction of lost monuments or parts of architectural heritage, like the reconstruction of the Roman aqueduct Anio Novus, Castelmadama, Rome [2], the reconstruction of the wall where the tower of Cadì is located in l'Alhambra, Granada [22], the church of Santi Maria e Stefano in Arezzo [2], the reconstruction of the fortress of Montecastrese in Camaiore [2] and other sites [2, 23, 24]. Starting from the historical investigation and the collection of the documentary sources received, such as vintage images, historical drawings, and documents related to the works carried out on the artefact, the aim is to reconstruct the original architectural speech of a fundamental element of urban architecture such as an urban gate. The case study sees the application of retro-planning to the city gate S. Lorenzo, which no longer exists [1], one of the six city gates of the historic city of Barletta (BAT), inserted in the 16th century curtain wall, a crucial element for those who had to access the interior of the walls and an emblem of the city's magnificence.

The correct reading and interpretation of the data constitutes the starting point for the digital transposition of the case study, from which a predictive 3D model of the architecture can be extrapolated, so that the image obtained can establish a correct correspondence with the original architectural spatiality gate S. Leonardo, thus guaranteeing verification of the hypotheses formulated.

The interpretation of the collected data, the study of the site of the original building and the historical period made it possible to reconstruct a correct knowledge of the architecture. By using back-planning and tools for digital representation, it was possible to recreate a representative model of the original state of the cultural asset studied.

## 2 The Retro-Planning

The contribution of digital modelling, with increasingly powerful software and hardware, has become the usual equipment of the designer and academic in the field of Cultural Heritage. Using them for the documentation, design, restoration and reconstruction of architectural artefacts.

Using the techniques of digital representation, retro-planning (Fig. 1) expresses the intention to carry out a backward design of an artefact, starting from the tangible remains, if any, or from the available iconographic representations, and then going backwards through the process that led to its realisation, until it is possible to reconstruct its original layout.

Retro-planning, precisely because of its reconstructive procedure, is a process that is never complete and always capable of drawing new inspiration, from remains and clues to trace back by successive intuitions to the definition of the original project [2].




**Fig. 1.** General outline of the methodology of a retroproject

The scope of this process, not surprisingly, is the unbuilt, destroyed or unfinished works, whose original architectural spatiality is to be known.

The starting point is undoubtedly the collection of information, which must be certain and accurate, since it forms the basis for subsequent operations.

Essential is the historical investigation, necessary to understand the context of the building, the function it had and the reasons that forced it into its current state or the lack of or partial realisation. Researching works coeval to the one being studied is useful for tracing any construction and dimensional analogies.

Often, especially for the oldest artefacts, the collection of information does not lead to a total knowledge of the object, but only to a series of traces, of clues, so it will be the skill of the researcher to discretise the information and find the intuition capable of uniting the available data into a plausible reconstructive hypothesis, to allow the digital model to be elaborated to present the original appearance of the factory.

Reverse planning, in order to be done correctly, requires a thorough knowledge of the historical period in which the work was created, its technical and cultural aspects, because it is only by understanding this that it is possible to convey the intentions of the original project and attempt to reconstruct what is no longer there, filling the void created by its destruction or unfinished work.

The task of the designer who performs such a reverse design is to seek continuity between the concreteness of the property of the past and the hypotheses developed in the present, by which is meant a historical moment very different from the one in which the work originated, both in terms of the materials used and the construction methods.

This design process needs to assume what is missing, starting from what is available, be it artefacts, drawings, images or reproductions of the past, while at the same time reflecting on the evolution of history and the disintegrating power of time, which can erase even what may seem indestructible.

Retro-planning thus achieves its highest goal, no longer being limited to an action on the imagination of the recipients but allowing them to grasp the essence of the lost work, through direct observation of how it would have looked today in the place where it was intended if the structure had still existed.

## 3 The Case Study: Porta S. Leonardo in Barletta

Gate S. Leonardo was one of the six city gates of the city of Barletta, part of the 16th-century defensive curtain (Figs. 2 and 3). It was one of the first to be built and the last to be demolished. It takes its name from the nearby church belonging to the Templar order, which was later destroyed following the abolition of the same knightly order.

The structure, of remarkable historical and artistic value, was embellished in 1793 with two coats of arms of the city of Barletta and an inscription commemorating the restoration. These details, now housed in the city museum (Fig. 4), are the only elements to have been saved from demolition. The coats of arms and the inscription were placed on the east elevation, i.e. the elevation facing outside the city walls so as to be visible to those arriving in the city, amplifying the monumental character and image of the city gate. In 1899, with the demolition of the defensive wall curtain, the structure was isolated, remaining free on all sides. The building, built on a yielding and inconsistent terrain, is subject to severe instabilities that affect its stability. In 1925, the gate underwent several consolidation works that did not have the desired outcome due to the incompetence of the company in charge. In the same year, the municipality decreed that it was impossible to carry out the restoration and decreed the demolition of the structure [1]. The resulting

material was to be used for the construction of the bell tower of the town church of the Holy Family, as can be read in the Municipal Council resolution of 26 August 1925.

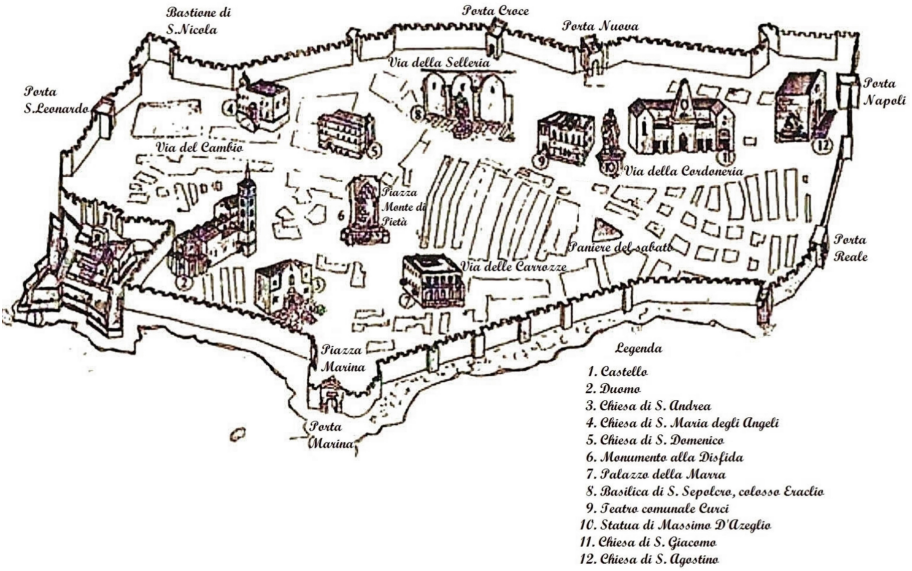


**Fig. 2.** Palma Cannito. Reconstruction of the plan of Barletta in the 16th century.

## 4 Data Acquisition and Processing

A very important stage in the process of carrying out a retrospective is the collection of all data and information relating to the object of study.

For the case under study, the available elements are vintage images, representing the east (Fig. 5) and west elevations of the gate, sketches and drawings of some details with dimensions (Figs. 6 and 7), a site plan (Fig. 8), made during the preliminary surveys for the renovation work to be carried out, and documents related to the same work carried out during the year 1925, until its demolition.

Specifically, the drawings and documents were extremely helpful in understanding elements that were not clearly visible in the available images.

The documentary sources found have been objectively and directly verified, since the two coats of arms of the city and the inscription, dated 1793, that appeared on the east front of the St. Leonard's gate, as well as the elements in stone material behind the same coats of arms and present on the back of the finds, have been preserved in the Civic Museum of the Swabian Castle of Barletta.

This material, which became the property of the Barletta Civic Museum following the demolition of the gate, are the only remains of the monument still preserved today, in memory of what was once a symbol and an element of identity of the city.




**Fig. 3.** St. Leonard's gate position in the current road system



**Fig. 4.** Coats of arms of the city of Barletta and stone inscription, additions made in 1793 on the east front of Porta S. Leonardo, Museo Civico di Barletta.

With the survey carried out on the artefacts, it was possible to carry out a true-to-life measurement, in order to have the real and certain dimensions of certain elements belonging to the monument under study, which could later be compared with those in the drawings found. The opportunity to have the two coats of arms available made it



**Fig. 5.** East elevation of Porta S. Leonardo, Fotorudy archive.

possible to carry out a photogrammetric survey, for the reconstruction of the 3D digital model (Fig. 9) and maps showing the original urban layout.

The latter is almost unchanged today, as it usually is, barring wartime or social upheavals. From a comparative reading of the defensive wall perimeter and the existing urban grid, it was possible to understand how Porta S. Leonardo was placed approximately in the center of the present-day Via Cavour. Its position was not orthogonal with

the axis of the road but inclined by five degrees. The gate, in fact, followed the same circular course as the city walls, as described in the rules for the construction of defensive walls [5, 6], where it is stated that access to the gates should not be perpendicular to the road, but inclined to the left, "because in this way the wall will face the right side of the attackers, which will not be covered by the shield" [5].

This planimetric layout is supported by the position of the buildings within the curtain wall that, even today, rise between Via Cavour and Via III Novembre and that, due to their location, make the sloping layout of the city gate obligatory. Another dimensional aspect verified is the depth of the building, comparing the dimensions read on some plans found with the numerical value obtained with the inverse perspective realised using the dimensions of the artefacts kept in the city's civic museum. Comparable values were obtained from the verifications, which made it possible to create a digital model realistic to what the original volume of the structure probably must have been. Otherwise, the vertical dimensions were well documented from the drawings found, so the dimensions of the missing friezes and decorations were obtained by photo-recording.

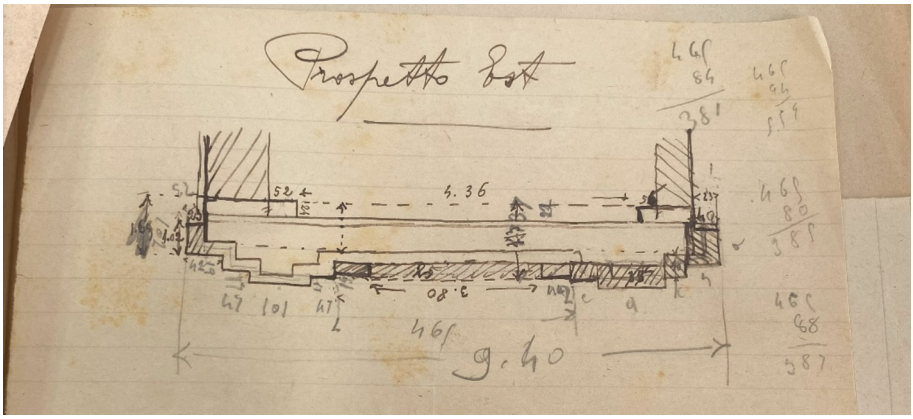


**Fig. 6.** Drawings of Porta S. Leonardo, Bari State Archives, Barletta section

## 5 The Digital Model of St. Leonard's Gate

Once the documentation has been completed, the next step is necessarily the creation of the drawings for the representation of the study subject, defining the graphical drawings necessary for the representation and modelling of the 3D digital model, of the architectural object (Fig. 10). This phase will be well thought out, as the choice of marks used, the drawing of lines for correct representation, will condition all subsequent steps in the processing of the digital model. A bad interpretation of the drawings found or the archive data on the materials used may compromise the representation and interpretation of the final model. The production of 2D drawings, the basis for processing the 3D digital model, involves knowledge of the rules of representation and the technique inherent in the use of CAD. The knowledge of the rules for representation are very important in

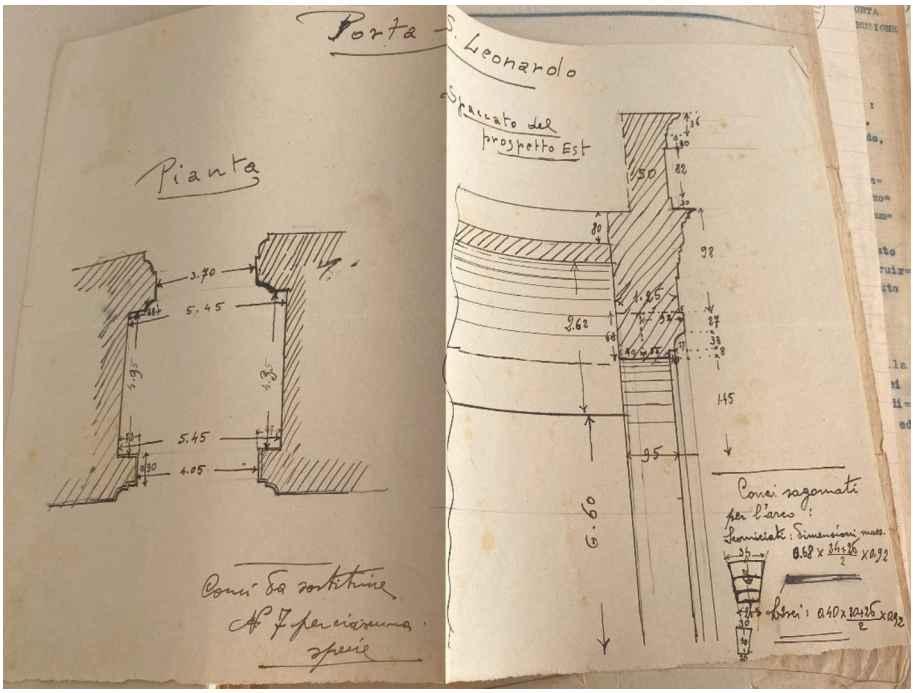


**Fig. 7.** Drawings of Porta S. Leonardo, Bari State Archives, Barletta section.

the retro-planning process, because it is in the representation that all the data collected converge, making them explicit in the graphic sign.

Extracting the drawing from historical data such as drawings, photographic representations or archaeological finds requires an uncommonly broad knowledge, which goes beyond that of the draughtsman. This phase, in fact, we can liken it to the phase in which the designer created the object of study. Thus, it is that phase in which there is the figuration of the design idea in the analogue drawing of the object on paper. Only later, thanks to the draughtsman's skill, can we make the transition from analogue to digital depiction to scale. The two-dimensional drawings produced for the retro-planning, "will not only have the purpose of producing drawings in accordance with some past style of drawing, but they are also in fact an important discretisation operation, they bring the spatial model back to historical forms of schematization, they bring thought back to the same steps of those who made that work" [2].

The need to represent traditional 2D drawings such as plans, elevations and sections, on which to base the digital model of the work, is a process of understanding the object being studied. Without the Mongiana representation drawings, it will not be possible to construct a three-dimensional model consistent with the information gathered. The 2D drawing elaborated with Monge's orthogonal projection theory involves further analysis to structure all the data collected, representing it in a homogeneous form that can be understood through drawing.

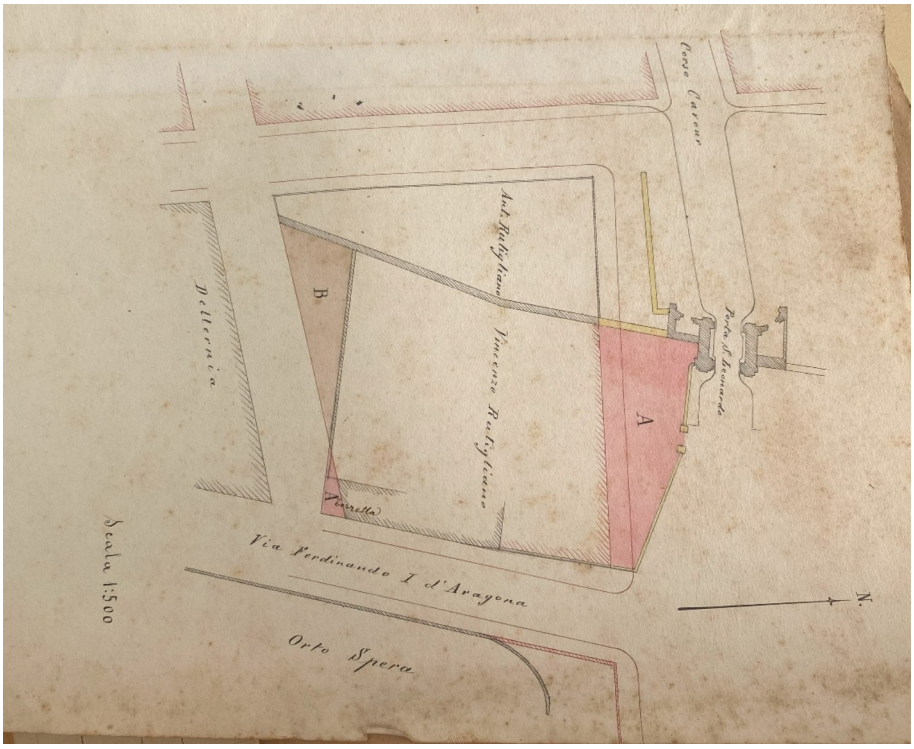


**Fig. 8.** Planimetry of the Porta S. Leonardo site, Bari State Archives, Barletta section.

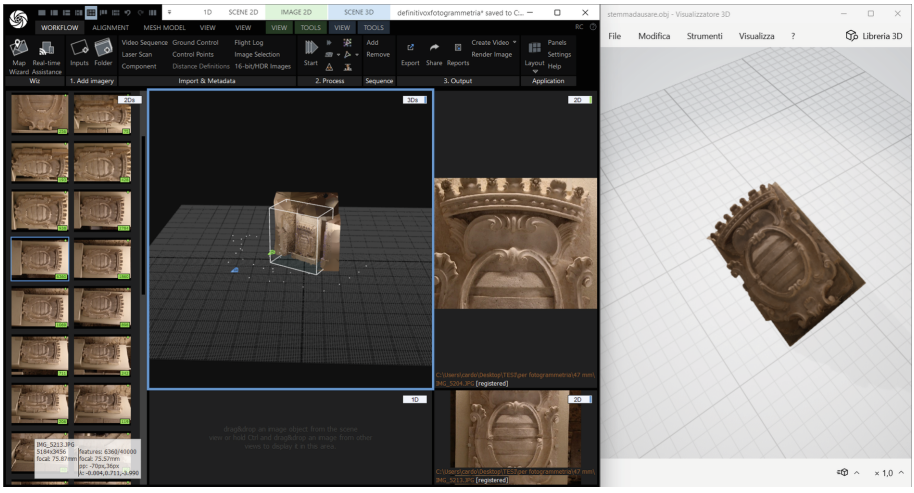


**Fig. 9.** Digital 3D model of the coat of arms of the city of Barletta using photogrammetry

As the entire S. Leonardo gate was destroyed, the only possible survey was carried out on the remains preserved at the museum in Barletta. Photogrammetry with *Realuty Capture* software was used to survey the coats of arms and the inscription preserved at the archaeological museum in Barletta. First, a series of photographs were shot with the camera, making a circular trajectory around each element to be surveyed, the images were taken with a fixed focal length of 35 mm. The focal length was determined by the need to include the entire element to be surveyed in the frame and for the layout of the exhibits within the museum. Subsequently, a few photographs were taken from a frontal position, varying the shooting height and keeping the focal length fixed.

The second step involves loading the images into the software, which automatically recognizes the correspondence of the various photograms in which the detected coat of arms or inscription is portrayed, superimposing them on each other to obtain, at the end of the processing, the 3D digital model of the detected element. Once the digital model of the coats of arms and the inscription was realized, the 3D digital model of the entire S. Leonardo gate was made, based on the 2D drawings processed using the historical data found. The models of the coats of arms and the inscription obtained from the photogrammetric survey were mounted on the 3D model, obtaining a photorealistic and true-to-life model of the gate (Figs. 11 and 12).

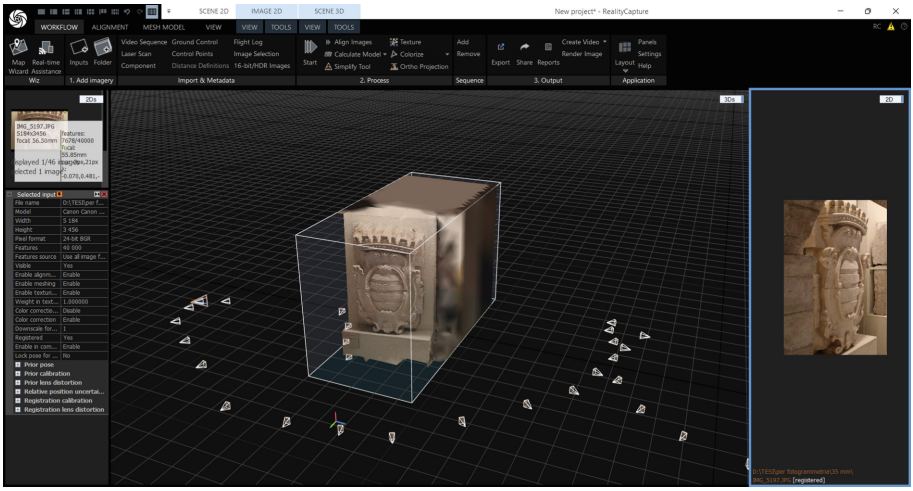

**Fig. 10.** Reality Capture. The photogrammetric survey reconstruction process.



**Fig. 11.** Barletta. Porta S. Leonardo. 3D rendering of the east elevation



**Fig. 12.** Barletta. Porta S. Leonardo. 3D rendering of the west elevation

## 6 Conclusions

The era we are living in is strongly influenced by new technologies and the spread of the Internet. Digital technologies have revolutionised the approach to the study and conservation of Cultural Heritage, changing the way we study, represent and visit them.

The computing power of today's computers makes it possible to represent what does not exist in a highly realistic manner. One only has to weigh the development that video games have undergone and how films have changed, which are increasingly being made using digital techniques to represent environments and scenarios that do not exist.

We can say that we are moving into an extended era, where digital representation is placed side by side with reality, creating digital worlds, even entire cities, with the metaverse, in which many large design studios and architects are engaged [3]. Inevitably, Cultural Heritage has also been touched by the innovations of digital technologies, enabling the reconstruction of works that no longer exist or are unfinished. The possibility of representing and showing all the features of a certain monument, building or statue has led to the development of specific solutions for different needs. Just think of 3D viewers to immerse and visit 3D digital models. All these new possibilities have given a boost to the knowledge, transmission and use of digitally depicted Cultural Heritage.

In normal design, the digital model is used to depict an artefact that does not exist. In back-planning, the digital model is used to visualise an architectural volume that was there but has now been lost, whose design has been fully or partially realised and which has already left its mark on time.

Retro-planning, requires a clear understanding of the new possibilities offered by digital technology, of the architectural language, of the technical and technological issues of the cultural asset being studied, but above all, it is essential to understand the thinking of the architects who conceived the work to be redesigned. This entails a significant abstraction to reach out and capture the philosophy and thinking of a period far removed from us. This mode of operation entails the need to reset all prior influences, rethinking from scratch the motive that drove the original designer of the good that is no longer present to make certain choices.

As we have seen, very often, the plans of the work have been lost, and reconstructing the history of the work studied is fundamental to its realisation but difficult to realise due to the lack of certain data that only a creative approach of the scholar will be able to deduce supported by his own cultural notions and the study of the oldest materials and construction techniques used at the time when the work was realised.

The reconstruction done on Porta S. Leonardo, compared with other similar experiences, reinforces the validity of the retro-design method. Among the various reconstructions already carried out, many started from the remains of architecture still present on the original site, such as the aforementioned Roman aqueduct Anio Novus, Castelmadama, Rome [2], or the walls of the tower of Cadì in l'Alhambra, Granada [22]. In the case study analysed here, there was no residual part of the architecture on which to base the reconstruction, this pushed the process to a higher level than previous ones, allowing this operative method to be taken to extremes, producing a 3D digital model based solely on research and historical analysis of the artefact.

A very difficult work where the use of computer technology becomes essential precisely because of its peculiarity of recreating virtual environments that can also be visited, so as to enjoy the reconstructed work. The cultural asset that has left its imprint in the passage of time, studied and reconstructed through retro-planning, is brought back to life in order to be placed again in the timeline, albeit in a digital manner, returning it to the cultural heritage as it was initially designed by its designer.

In this way, the digital model of the reconstructed work allows it to live on and be remembered forever.

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## References


1. Resolution of the Municipal Council at its meeting on 12 August 1925
2. Verdiani, G.: Retroprogettazione. didapress, Firenze (2017)
3. Mongiello, G.: Metaverse: The architectural speech of digital representation. In: 20th World Heritage and Ecological Transition, pp. 384–389. Gangemi, Roma (2022)
4. Grellert, M., Pfarr-Harfest, M.: 25 Year virtual reconstruction, Currente Challenges and the comeback of physical model. In: Act of Digital Heritage Congres. Marsiglia (2013)
5. Pollione, M.V.: De Architettura. Edizioni Studio. Firenze (1999)
6. De Seta, C., Le Goff, J.: La città e le mura. Laterza, Bari (1989)
7. Ascani, V.: Il Trecento disegnato. Le basi progettuali dell'architettura gotica in Italia. Viella, Roma (1997)
8. Benevolo, L.: Storia della città: la città medievale. Laterza, Bari (1993)
9. Benevolo, L.: Storia dell'architettura del Rinascimento. Laterza, Bari (1968)
10. Bini, M., Bertocci, S.: Manuale di rilievo architettonico e urbano. Città studi, Torino (2012)
11. Cassandro, G.I.: Le pergamene della città di Barletta 1186–1507. Vecchi (1993)
12. Cassandro, G.I.: Barletta nella storia e nell'arte. Rizzi & Del Re, Barletta (1957)
13. Doronzo, G.: I borghi antichi di Barletta. CRSEC, Barletta (2003)
14. Musso, S.F.: Recupero e restauro degli edifici storici. EPC, Roma (2016)
15. Bitelli, G., Girelli, V., Vittuari, L.: The potential of 3D techniques for Cultural Heritage object documentation. In: Videometrics IX, Proceedings of electronic imaging science and technology. SPIE, USA (2007)
16. Cozzi, M.: Antonio da Sangallo il Vecchio e l'architettura del Cinquecento in Valdichiana. SAGEP, Genova (1992)
17. Docci, M., Maestri, D.: Manuale di rilevamento architettonico e urbano. Laterza, Bari (2009)
18. Grün, A., Remondino, F., Zhang, L.: Photogrammetric reconstruction of the great budha of Bamiyan, Afghanistan. In: The Photogrammetric Record n. 19 (107), pp. 177–199. Blackwell Publishing Ltd, UK (2004)
19. Guidi, G.: 3D visualization of cultural heritage artefacts with virtual reality devices. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 25th International CIPA Symposium. Taipei, Taiwan (2015)
20. Le Goff, J.: L'immaginario medievale. Laterza, Bari (2011)
21. Verdiani, G.: I nuovi strumenti hanno compiuto quarantatré anni. In: La documentazione dei Beni Architettonici ed Ambientali, strumenti, indagini esperienze. Saffe, Firenze (2006)
22. Rodríguez-Navarro P., Cabezos-Bernal P.M.: Aplicaciones de la cámara Gopro para la toma de datos de arquitectura. In: APEGA 2014, XII Congreso Internacional Expresión Gráica aplicada a la Ediicación Graphic Expression applied to Building International Conference, Proceedings, Universidad Europea de Madrid (2014)
23. Belli, G., D'Andrea, S.: From Porta alla croce to piazza beccaria the evolution of florence from city to capital. In: Rodriguez-Navarro, P., Verdiani, G., Cornell, P. (eds.) Architecture, Archaeology and Contemporary City Planning "State of Knowledge in the Digital Age". Valencia, Spain, Lulu Press, USA, (2015)

24. Guidi G., et al.: 3D visualization of cultural heritage artefacts with virtual reality devices. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-5/W7, 2015 25th International CIPA Symposium. Taipei, Taiwan (2015)
25. Amico, N., Ronzino, P., Felicetti, A., Niccolucci, F.: Quality management of 3D cultural heritage replicas with CIDOC-CRM. In: CRMEX 2013 Practical Experiences with CIDOC CRM and its Extensions. Proceedings of the Workshop, Malta (2013)
26. Apollonio, F.I.: Classiication schemes and model validation of 3D digital reconstruction process. In: Börner, W., Uhlirz, S. (eds.) Proceedings of the 20th Cultural Heritage and New Technologies, Museen der Stadt Wien — Stadtarchäologie, Vienna (2016)
27. Kula, W.: Le misure e gli uomini dall'antichità a oggi, traduzione di Anna Salmon Vivanti, collana Storia e società, Laterza, Bari (1987)
28. Monti, C., Selvini, A.: Topograia, fotogrammetria e rappresentazione all'inizio del ventunesimo secolo, Maggioli Editore, Rimini (2015)
29. Rodríguez-Navarro, P.: Automated Digital Photogrammetry versus the systems based on active 3D sensors, «Revista EGA», n. 20, a. 17, Valencia (2012)