SCIRES it
SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 11, Issue 1 (2021), 115-132
e-ISSN 2239-4303, DOI 10.2423/i22394303v11n1p115

CASPUR-CIBER Publishing, http://www.sciresit.it

GHIBERTIANA PROJECT: TOWARD THE 'INTERPRETATION CENTER OF THE VALDISIEVE TERRITORY'

Alessandro Merlo, Gaia Lavoratti*, Giulia Lazzari*, Alessandro Manghi*, Matteo Bartoli**

* DIDA | Department of Architecture – University of Florence – Florence, Italy.

Abstract

The reflection on the inclusive and widespread use of the cultural heritage, already in place in the last decade, but exacerbated by the health emergency that began in March 2020, has stimulated the proliferation of alternative experiences that make extensive use of ICT. The variety of tools available has generated a multiplicity of technical solutions based however on the essential operation of the digitisation of the heritage, promoted for years by MiBACT and today even more urgent. This contribution aims to illustrate the work in February 2020 within the "Ghibertiana" project for the preparation of the digital contents of the soon-to-be-established "Centro di Interpretazione del Territorio della bassa Valdisieve" (Interpretation Centre of the Lower Valdisieve Territory) and "Centro di Documentazione su Lorenzo Ghiberti" (Documentation Centre on Lorenzo Ghiberti).

Keywords

Digital Cultural Heritage, ICT, Digital Twin, Museum 4.0, Ghibertian Project, Valdisieve.

1. *The Ghibertian Project*

"Ghibertiana"[1] is a complex, interdisciplinary and multiscalar project, aimed at enhancing the link between the cultural heritage of lower Valdsieve[2] and the works of Lorenzo Ghiberti (Pelago, 1378 – Florence, 1455), who was born in this land and invested part of his fortunes here.

The project, which started in 2018, provides for the creation of the "Documentation Centre on Lorenzo Ghiberti" – in which all information relating to the artist and his works will be collected in dematerialised form, allowing scholars to have a place dedicated to research on the master – and the "Interpretation Center of the Lower Valdisieve Territory", where it will be possible to grasp those elements present in the early fifteenth century in the Florentine countryside landscape, which Ghiberti often depicted in his works and which still remain today as a indelible sign of human work.

The result of the collaboration between the University, the Region, Municipalities and local communities, the "Interpretation Centre" will function as a *Hub* for all cultural operators already present *on site*, networking and enhancing the synergies between the various *stakeholders*[3], in order to achieve the full implementation of the concept of the "dispersed museum" (Lupo & Özdil, 2013) (Figs. 1-2).

[1] "Ghibertiana" is a university project originating from the collaboration between the Department of Architecture (DIDA) and the Departments of History, Archaeology, Geography, Art, Entertainment (SAGAS), Agricultural Sciences and Technologies, Environmental and Forestry Food (DAGRI) and Information Engineering (DINFO) of UNIFI (University of Florence). Alessandro Merlo and Giuseppina Carla Romby coordinate the Project; in addition to the latter, the Scientific Committee comprises Paolo Clini and the managers of each of the exhibition halls of the "Centre for the Interpretation of the Territory of lower Valdisieve" (Dora Liscia Bemporad, Paolo Nanni, Francesco Salvestrini, Guido Vannini with Chiara Molducci).

[2] Term used to historically indicate that part of the Florentine countryside lapped to the north by the Sieve river, bordered to the west by a section of the lower Valdarno, to the south by the Pratomagno ridge which divides it from the Casentino and to the east from the Mugello and which today includes the municipalities of Pelago, Pontassieve, Londa, Reggello, Rufina and San Godenzo.

[3] In the last three years, agreements have been formalised with the Opera di Santa Maria del Fiore, the Opificio delle Pietre Dure, the Accademia dei Georgofili and the Museo dell'Opera del Duomo. As regards the agreements with local authorities, the project involves the Union of Municipalities of Valdarno and Valdisieve and the Region of Tuscany. For the digitisation of the cultural heritage, the working group makes use of the collaboration of the Polytechnic University of the Marche and, in particular, of the DiStoRi Heritage.

Fig. 1: Map of the settlements of the Guidi in the area around Florence (elaboration).

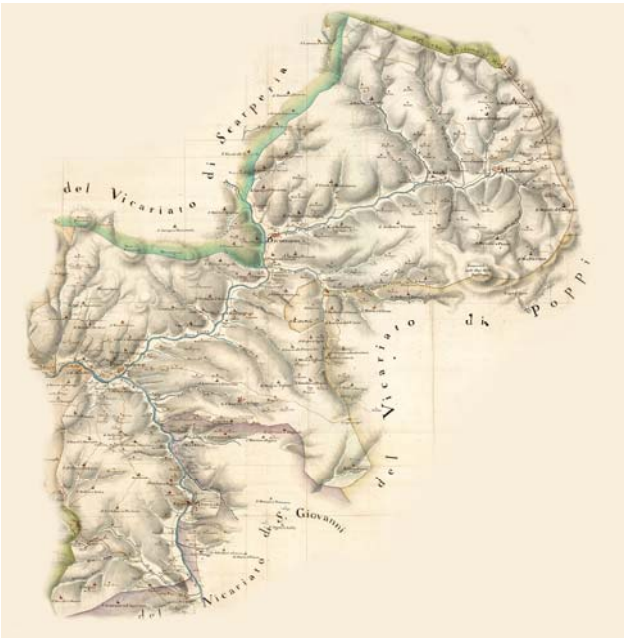

Fig. 2: Vicariate of Pontassieve (Ing. Morozzi Ferdinando, 1780, original scale 1: 33060, Nàrodni Archiv Praha).

The Project also proposes, in line with the regional policies of delocalisation of tourist flows from Florence (cfr. PON Metro Firenze 2014-2020, Azione 1.1.1), to draw to the territory of the lower Valdisieve those who, also attracted by the notoriety of the artist – the international fame of Ghiberti, who has not yet been given sufficient prominence either through dedicated cultural structures or through renewed historiographical studies, is capable of moving large masses of people – are willing to embark on an alternative cultural experience.

The "Interpretation Centre of the Lower Valdisieve Territory" and the "Documentation Centre on Lorenzo Ghiberti" will be housed in the fourteenth-century Palazzo Comunale located inside the castle of Pelago. This historic building owned by the municipality of the same name was restored in 2017 for museum purposes and, since 2018, has been assigned to the Project.

The arrangement of the rooms, currently under construction, will proceed in batches starting with the large room on the ground floor and then continuing with the rooms on the upper floor where the "Interpretation Centre" will be located. The latter will be organised on the basis of the specifications provided for museums 4.0 (MiBAC, Piano triennale per la Digitalizzazione e l'Innovazione dei Musei – DG-MU 19.07.2019 n. 892) and will be able to propose different contents from time to time recalling them from the respective databases. Digital copies (DT), 3D animations, Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) constitute the *assets* that will allow alternative ways of using the digitised heritage (Gabellone, 2019). In turn, each room will host a limited number of *exhibits* which will be given appropriate prominence through an installation created *ad hoc*. Finally, the use of special sensors will enable profiling of visitors and, based on their interests, offer them personalised contents, as well as optimising their visit.

The core of the "Documentation Centre on Lorenzo Ghiberti" is in turn made up of a database which contains the summary of articles, essays and monographs on Ghiberti and his works, recorded in the form of factsheets inside an Omeka portal hosted in the UNIFI Library System. To date, 162 factsheets have been created, each usable in two languages, through which it is possible to geo-localise the material and the works described, cross-search using keywords and, finally, download/view digitised texts and images to which the factsheets refer.

The studies on the master are also supported by the activity of the "International Centre of Ghibertian Studies – APS", with the opening of a library fund reserved for him and by constant dialogue with the bodies responsible for the custody, protection and enhancement of his works. On the Ghibertian Project cf. http://www.ghibertiana.it/.

2. The "Interpretation Centre of the lower Valdisieve"

In the Interpretation Centre it will be possible to decode in the correct historical perspective the places of greatest interest in the territory of the lower Valdisieve, the so-called 'Terre del Ghiberti', through five interpretations: the crop landscape, the castles of the Guidi family, the Vallombrosa forest and abbey, the working of noble metals and the Ghiberti workshop, the Gates of Paradise of the Florence baptistery.

Between the end of the fourteenth and the beginning of the fifteenth century, Valdisieve witnessed the progressive loss of power of the Guidi family and, more generally, the progressive decline of feudalism and its centuries-old practice of exploitation of extra-urban territories, which in the Tuscan countryside was quickly replaced by sharecropping. Castles, parishes and fortified towers that belonged to the Guidi family became part of the assets of the wealthiest upper-middle-class families who had established themselves in Florence more than a century earlier and of the powerful Vallombrosa abbey. Once their role as outposts for the control of the territory ceased, these structures were used as grange-farms (agricultural administrative units) in which the products of specialised crops were processed and stored. This new organisation of the anthropic landscape constituted, in the extra-urban area, the distinction between the Middle Ages and the modern age. With the exception of some slight differences introduced in the last hundred years, this is still the scenario that characterises the lower Valdisieve, within which it is still possible to recognise the elements of permanence as significant/identifying the present day (Molducci, 2015; Barlucchi, 2015; Vannini, 2009).

Lorenzo Ghiberti is, in the artistic field, one of the protagonists of this change. The doors known as the Gates of Paradise of the Florence Baptistery, built by the master between 1427 and 1452, are in fact recognised by art critics as one of the works that mark the transition from Medieval to Renaissance art (Krautheimer, 1970). The bronze bas-reliefs, both from an iconographic and a technical point of view, reveal a marked difference compared with the previous production, even by the same master. Already the results of the well-known competition of 1401, which saw a very young Ghiberti prevail over Filippo Brunelleschi and which earned the master the assignment of making the second door[4], highlighted not only his extraordinary skills as a sculptor and engraver, but above all his use of a new casting technique that allowed the creation of thin and more easily modelled surfaces (Giusti, 2015). With the third door, breaking with a millenary tradition that had seen the previous ones decorated with a large quantity of single panels (28 in the case of the first door by Andrea Pisano and of the second), the author describes the stories included in the first books of the Bible in just ten panels (sometimes up to nine episodes collected in the same work), at the same time abandoning the quadrilobes and using the square format in their place (Giusti & Radke, 2012). And it is precisely in the elements that he depicts in it that, more than in his other works, it is possible to recognise the landscape of the Florentine countryside in the different components that characterise it: the plant components, as well as the natural ones, the cities, the farm buildings and the cultivated fields, of which he had direct experience.

Once the museological programme had been finalised, considering the limited areas (130 mq) available to the "Interpretation Centre", it was necessary to reflect on the museological one, considering the solutions available today. Museums 4.0 by their very nature do not require large spaces (cfr. Museo della via Flaminia a Fano, Museo Leonardiano a Vinci, Cooper Hewitt Museum a New York, Museum of Digital Art di Zurigo); their innovative character lies precisely in being able to have potentially unlimited contents, archived on computer media, to be recalled on special devices in order to be used. Today there is no sense that cannot be alerted through the most advanced devices, allowing the visitor to engage in visual, auditory, olfactory and, if necessary, tactile experiences by interacting with the virtual world. In the "Interpretation Centre" it will therefore be possible to experience *infotainment* and *edutainment* (Agostino & Arnaboldi, 2021) which will lead the visitor through that early 15th century landscape from which Ghiberti drew inspiration in his works, in particular in the ten panels of the Paradise Gate of the Baptistery of San Giovanni in Florence.

[4] Of the three doors of the Florence Baptistery, Ghiberti was commissioned to make two of them: the second (1403-1424) with the Stories of the life of Christ, and the third (1425-1452) in which the Old Testament Stories are depicted.

2.1 The exhibition itinerary

The exhibition itinerary starts in the 'large room' located on the ground floor of the former Town Hall and set up for immersive projections. A video entitled "The lands of Ghiberti" will enable the visitor to understand the aims of the project and to acquire the first rudiments to orient himself within the Interpretation Centre. This same space, designed to allow for a variety of uses, will also host conferences and temporary exhibitions.

On reaching the first floor, the visitor will be gradually introduced into the fifteenth century landscape of the Valdisieve (first and second room), of which the peculiar characteristics that still today characterise and identify this territory will be highlighted. A model in scale 1: 25.00, made of plastic material and without *texture*, will have the task of delimiting the area from a geographical point of view, thus allowing it to be differentiated from the neighbouring territories (Casentino, Mugello and Upper Valdarno). Images and short films will be projected on this model which, with the support of a narrator, will enable visitors to grasp the evolution over time of the main anthropic components (buildings, paths, crops, etc.) and natural ones (wooded areas, water courses, reliefs, etc.) that characterise it.

Three themes are the object of specific in-depth studies: the *Conti Guidi* castles, the specialised cultivations and the Vallombrosa abbey with its forest. In the first case, through an *App* available on personal devices, it will be possible to consult a physical map depicted on one of the walls, locate the artefacts in the area, distinguishing them by form and function and call up specific factsheets. The understanding of the formal and geometric characters of the most emblematic buildings will be entrusted to 1:50 scale models, obtained through 3D printing, starting from the data of the digital survey. By means of *Augmented Reality* systems it will be possible, again on the visitors' devices, to view these same models equipped with the *texture* of their apparent colour, thus also being able to appreciate the chromatic information. A video will narrate the historical-territorial events between encastellation (especially in relation to the Guidi phase) and decastellation (following the 'conquest of the countryside' by Florence), with particular reference to the Ghibertian age (definable as the first "autumn of the Middle Ages" or early Renaissance).

As far as the agricultural landscape is concerned, the historical iconography on the one hand and the cartographic reconstructions on the other will enable us to understand the changes that have taken place in the territory following the establishment of farm sharecropping. 3D animations will illustrate in detail this new form of rural management, relating the constitution of land units (farms and pieces of land) to the new forms of living (houses for nobles and for workers) and associated cultivation, which united herbaceous and arboreal cultivations (vines and olive trees).

Finally, the environmental, ecological, biogenetic and botanical characteristics of the 'domesticated' forest of Vallombrosa and those linked to the territorial function that the powerful abbey of Santa Maria Assunta has played over the centuries will be described through the copious iconography kept in the library of the same abbey and a video that summarises the present and past use of forest products.

A *focus* on metalworking, well documented in this territory since the time of the Signoria, aims to strengthen the role of the Valdisieve both as an important junction of routes that from the neighbouring regions headed towards Florence and the lower Valdarno, and as an area for trade, through the markets, of wrought iron, products of wooded areas and wool. This in-depth study, also entrusted to a video which explains the work done in a blacksmith/goldsmith's workshop, enables us to introduce the figure of Lorenzo Ghiberti and his masterful technique of working with noble metals (casting, refinishing, embossing, chiselling, gilding, enamelling) which the master used with particular skill and which made him famous even in the eyes of his peers.

In the third room Ghiberti's hologram will tell of some portions of his biography serving to underline his link with the Valdisieve and to illustrate the goldsmith's works that more than the others have circulated outside Tuscany. Starting from the images of the main creations, visitors will be able to interact on their devices with the high definition 3D models of the latter, discovering the most hidden details.

The fourth room will act as a register of the master's works; on each wall there will be a photograph (each entrusted to a different artist) of one of the works attributable to the different fields of art that characterised Ghiberti's varied production (with the exception of the goldsmith's

art, the subject of the previous room): the large bronze statuary, the terracottas, the stained glass windows and the panels. Using an image recognition app it will be possible to access a database (https://sbafirenze.it/ghibertiana/) which allows not only to open in-depth factsheets on each work belonging to the four categories mentioned, but also to know where these are currently stored. On four monitors placed in correspondence with each photograph, films will be displayed that briefly illustrate the master's production, placing it in the correct historical perspective.

The fifth and last room, dedicated to the ten panels of the Gates of Paradise, will close the exhibition and narrative path. Here, starting from the copies in a plastic material of the panels themselves, the visitor will be able to virtually enter the landscapes that Ghiberti depicts, virtually modelled starting from the digital data available on the door. Short 3D animations, in which the episodes of the Bible relating to the stories of the prophets will be highlighted and explained by a narrator, will enable the visitor to appreciate the master's ability, to decode the messages contained in the panels and, last but not least, to identify the elements of the fifteenth century Tuscan landscape which, mediated by art, were depicted *ad aeternum* on the ten panels.

3. Documentation and enhancement of Conti Guidi architecture

During the 11th and 12th centuries the Valdisieve fell under the dominion of the powerful family of the Guidi Counts, former lords of the Arezzo area and later also of the Empoli area. They had fully understood the strategic importance of this area, located on the border of the Florentine countryside, which allowed them to control the expansionist aims of the rich Florentine bourgeoisie (Vannini & Molducci, 2009).

The presence of the Guidi family was ensured by the numerous castles, walled villages and religious buildings under their direct control or that of their affiliates. Their hegemony on these lands continued until the fourteenth century, when Florence gradually regained possession of the frontier territories; in this context the Valdisieve, which did not hold a particular interest for the central power, began a slow decline which had a particularly inclement effect on the architectural heritage (Cherubini, 2009).

Fig. 3: Remains of the keep and the portal of the castle of San Leolino (photogrammetric elaboration).

Today there are numerous testimonies of that era and the crown of castle and parish structures erected around Florence is still clearly visible. The interest in these structures, sometimes almost intact to this day, in other cases documentable only through their fragments, has prompted the multidisciplinary work group engaged in the research – which sees the presence of historians, art historians, architects and archaeologists – to identify in the castle of Nipozzano and in that of San Leolino, in the church of Santa Maria a Ferrano, in the remains of the parish church of San Gervasio and in that of Magnale, the "pilot" artifacts on which to concentrate the first historiographical, archaeological and architectural studies and, at the same time, to define the most suitable ways to make them usable within the Interpretation Centre.

Among the first operations carried out by the working group were those aimed at documenting the morphometric data of the properties under investigation. The latter can be classified in two distinct categories: the first includes buildings that are in a state of decay made even more evident by the presence of "long-lasting" overgrown vegetation (San Gervasio, San Leolino and portions of Nipozzano), but which retain numerous original elements (usually a sign of early abandonment); the second includes those artifacts which, despite being in a good state of conservation, have been the subject of numerous restoration interventions, so much so as to make it difficult to identify the elements attributable to the period in which they were erected (Magnale, Ferrano and numerous buildings in Nipozzano).

As usually happens in the study of historical architecture, the morphometric survey is called upon to fulfill at least two purposes: to document geometric information that is gradually being lost and to deduce the data necessary to be able to define the changes that have occurred over time (Clini, 2011).

Of the castle of San Leolino (Fig. 3), a fortification that can be dated back to as early as 1164, there remains a triangular section tower, with bevelled and rounded corners, in which there is a large portal placed on a rocky wall that rises above the territory below; the cistern located underground, which is accessed via a staircase, still remains in a good state of conservation. The wood in which it is located, together with the collapse of all the horizontal structures and many of the vertical ones, almost entirely hides what remains of the building, so much so that the acquisition and subsequent recording of data is particularly problematic[5].

The castle of Nipozzano (Fig. 4) is undoubtedly one of the complexes that has remained in the best condition since it has undergone much restoration work over time. The building stands among the vineyards of the Frescobaldi estates, dominating the Sieve valley with an imposing keep[6] and two minor towers, flanked by a small village and the church of San Niccolò, dating back to the sixteenth century[7]; the latter, like the castle, was largely rebuilt following the damage suffered during the Second World War. The North-West area, now in a state of ruin, has some portions of masonry dating back to the beginning of the 11th century. With the exception of this area, for which the difficulties are similar to those encountered in San Leolino, the survey operations of the remaining areas did not present any particular problems and were carried out both by laser scanners and by aerial and terrestrial photogrammetry[8].

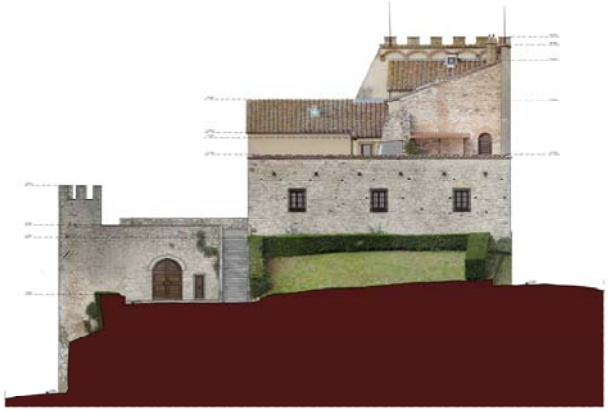

Fig. 4: The castle of Nipozzano: East front (elaboration).

Fig. 5: North front of the church of San Niccolò in Magnale (elaboration).

The castle of Magnale, whose toponym denotes an Etruscan origin, is mentioned in the documents relating to the nearby Vallombrosa Abbey starting from 1103. The current appearance of the complex (Fig. 5) is the result of the substantial changes that were made in the mid-eighteenth century, the extent of which can be identified by observing the ashlars adjacent to the entrance portal of the church, the lateral front on which are the cemetery and the walls that support the complex on the side towards the valley. In this case the survey[9] has documented artifacts that are still used and whose state of maintenance is to be considered more than good; this made it possible to obtain a complete

[5] Equipment used: Z + F 5006h laser scanner, DJI Mavic mini 2 drone, Nikon D3200 camera with Nikon 18-55 lens. 24 scans and 482 photographs were made, from which a dense cloud of 2.3 x 10^8 points was obtained.

[6] The main feature of the building is the complex planimetric arrangement, with various floors at different levels. On the ground floor there is the entrance courtyard, protected and surrounded by a walkway with lookout towers above which the massive main building rises, surmounted by a high tower. A U-shaped walkway surrounds the keep in the upper part, at the centre of which there is the stone portal that leads into the upper courtyard; this, smaller than the external one has two openings on the left, one on the right and the staircase leading to a small gallery supported by shelves, the last remnant of the highest portion of the building prior to its destruction of the 1944.

[7] The current position of the building can be documented at least since 1755 based on a cabreo from Villa Albizzi. There are traces of a previous church but located near the southern walls, in the central part of the village, as shown by a depiction of Scipione Ammirato from 1573.

[8] Equipment used: Z + F 5006h laser scanner, DJI Mavic mini 2 drone, Nikon D3200 camera with Nikon 18-55 lens. 114 scans and 3889 photographs were made, from which a dense cloud of 2.3 x 10^9 points was obtained.

[9] Equipment used: Z + F 5006h laser scanner, DJI Mavic mini 2 drone, Nikon D3200 camera with Nikon 18-55 lens. 45 scans and 953 photographs were made, from which a dense cloud of 2.3 x 10^8 points was obtained.

Fig. 6: Remains of the church of San Gervasio (authors' photo).

Fig. 7: The complex of Santa Maria in Ferrano (photogrammetric elaboration).

morphological and chromatic description of the various fronts and of the interior of the church.

Completely different is the case of the parish church of San Gervasio (Fig. 6) dating back to 1164; from the few remaining structures it is possible to deduce little more than the ground system. The vegetation that almost entirely covers the structure has made survey operations very difficult[10].

The last complex examined consists of the parish church of Santa Maria a Ferrano and the neighbouring village (Fig. 7); both have been the subject of restorations even in very recent times and are therefore in excellent condition. On a first brief analysis, the building structure seems to present some elements dating back to the time of construction[11]; the data acquired[12] and subsequent restitutions will allow us to investigate the first hypotheses.

3.1 Tools and methods for morphometric and chromatic documentation

Although in the era of the 4.0 restitutions the traditional two-dimensional drawings may be obsolete, it is certain that plans, sections, elevations and floor plans, in addition to orthophotos, still represent the essential starting point for an in-depth reading of an artifact (Bianchini, 2014).

In the present research the latter have made it possible not only to define the shapes, geometries and dimensions of the architecture investigated, but they were indispensable, for example, for the analysis of the elevations (subdivision into Wall Stratigraphic Units and recognition of the Buildings) according to the light archaeology indications. The walls of historic buildings are in fact a palimpsest in which it is possible to trace the interventions of "construction" (by man) or "destruction" (both by man and by nature), which when correctly interpreted make it possible not only to identify the mutual relationships between the distinct parts of a building, but above all to hypothesise a chronological sequence of events that have occurred over the centuries.

In this specific case, with the chromatic data, obtained through the well-known digital photogrammetry procedures and rendered in the perspective rectifiers, it was possible to recognise and represent the distinct building materials, the construction techniques used and the possible presence of decorations or marks left by the builders (Fig. 8).

Starting from these data it will be possible to obtain 3D reconstructions of the original configurations of the artifacts, the creation of three-dimensional prints and the display on digital copies of the analyzes made on the walls.

[10] The instrumental survey was also conducted despite the difficulties of access. Equipment used: Z + F 5006h laser scanner, DJI Mavic mini 2 drone, Nikon D3200 camera with Nikon 18-55 lens. 17 scans and 257 photographs were made, from which a dense cloud of 2.3 x 10^8 points was obtained.

[11] For example, it is possible to observe how in the apse, near the central single lancet window, there is a bas-relief with floral motifs, attributable to the workers who worked around the twelfth century at the nearby church of Ristonchi.

[12] Equipment used: Z + F 5006h laser scanner, DJI Mavic mini 2 drone, Nikon D3200 camera with Nikon 18-55 lens. 48 scans and 1699 photographs were made, from which a dense cloud of 2.3 x 10^8 points was obtained.

Fig. 8: One of the analysis made on a front of the settlement of Nipozzano (elaboration).

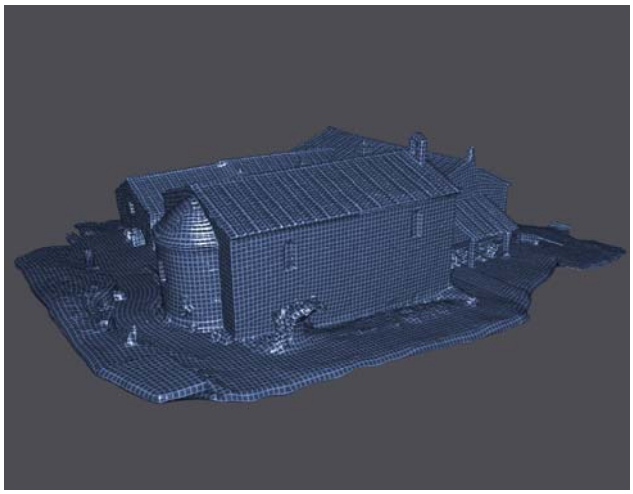

Fig. 9: The quad-dominant mesh of the low-poly model of Santa Maria in Ferrano.

The possibility to access to a three-dimensional view of the digital copies of the artefacts, documented through modern technologies, within a specially dedicated physical museum – the nascent "Interpretation Center of the lower Valdisieve" – will allow to promote a process of dissemination of knowledge of the artifacts examined, and of the scientific studies carried out on them, outside a strictly research area, through an immersive and interactive experience. In this way it is also possible to know those places of considerable historical importance that are often inaccessible (Bordoni & Pierattini, 2011).

For these purposes, the polygonal models extracted using Agisoft Metashape software have undergone to refinement and optimization procedures.

Once the problems related to the mesh geometry were solved within the 3D Systems Geomagic Design X[13] programme, each model was imported into the Blender software in which it was possible to define two workflows based on the needs for the final output (Minto, 2013). In the case of the creation of a three-dimensional print of the artifacts, it was sufficient to check that the *high-poly* models did not have holes on the surfaces (it was therefore decided that the border of the model should have no interruptions) and proceed with the conversion into the format suitable for 3D printing operations. In the one in which, instead, the models were used for AR (augmented reality) or MR (mixed reality) applications, further steps were required. The models produced by photogrammetry in fact have a high level of detail and consequently a large number of polygons, which are difficult to manage in real-time rendering. In the first place, we proceeded to a carry out a decimation of the *meshes* and their optimisation in order to obtain *medium-poly* models. It was deemed appropriate to further reduce the number of polygons through a process of *retopology* (creation of isotropic meshes) created with the Instant Mesh software in order to obtain a low-poly quad-dominant *model* (Fig. 9)[14]. This operation entailed a simplification of the level of detail of the original *mesh* which was subsequently reintroduced through the use of the *normal maps* and the *diffused colour maps* obtained following the parameterisation[15] of the *information baking models and processes*, created starting from the *high-poly* models using the Blender programme.

Following the refinement of the 3D model, it was also necessary to optimize the texture. In this context, the unwrapping process of the mesh as well as the baking of the maps previously

[13] Correction of non-manifold *geometries*, *clusters*, *dangling faces*, and overlapping polygons.

[14] The operation was carried out on Instant Meshes to test the potential of the free software and automatically obtain square isotropic meshes. The *retopology* operation could have been carried out on the Foundry Luxology Modo *software* which would have allowed a semantic subdivision of the elements (it is possible that in the continuation of the work it will be preferable to alternate the procedures based on the product specifications).

[15] Parameterisation of the texture in Blender generally provides better results than would have been possible by exporting the one obtained directly from Agisoft Metashape.

introduced is of fundamental importance. Unwrapping can be performed on any 3D modeling software but even in this last step the workflow is continued on Blender, where it is possible to obtain a satisfactory automatic unwrap for the intended purposes. This allows to obtain a better organized UV map – in well-defined islands – compared to the normal parameterization, difficult to process in post-production, obtained by exporting the model with the respective texture from Agisoft Metashape. The next step involved a new import on the latter program for a new and definitive calculation of the textures, this time carried out by activating the "Keep UV" option in order to maintain the work previously done. By importing and comparing the high-poly and low-poly models, which now share the same UV map, it was finally possible to perform the aforementioned baking procedure automatically on Blender, managing to transfer the information from the high-detail mesh to the simplified one. Thanks to these procedures it was possible to obtain a three-dimensional model that is correct and easily manageable by the software used for augmented reality.

Once the operations on the models were completed, it was possible, for example, to import them into a graphic engine that allows the development of interactive content: in the research project in question, Unity by Unity Technologies was used, integrated with the Vuforia Augmented Reality *plug-in*.

Augmented reality, unlike other forms of 3D use of digital content, allows you to always have a close relationship with reality to which a set of information related to 3D models is added. Within Unity it is therefore possible to work on the imported photogrammetric model by implementing the information it can provide in augmented reality using scripts and by inserting additional three-dimensional objects to complete the scene. In the specific application illustrated here, it is possible to distinguish two different ways to access digital content: *marker based* or *markerless based*. In the first case, a two-dimensional or three-dimensional target is provided which allows the *device* to read real information and correlate it with virtual data. The *markerless based* system instead uses GPS (in the case of *Location Based* AR) or (*Markerless* AR) images to activate the same data (Alvaro-Tordesillas, Crespo-Aller & Barba, 2019).

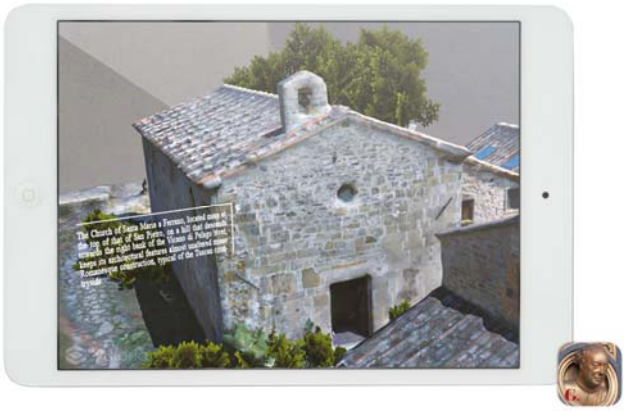

Fig. 10: Representation of the augmented reality App developed with Unity and Vuforia.

Once the model has been defined in its entirety and the debugging procedures have been carried out in order to verify the integrity of the scene just created, the Unity project was exported so that it could be opened in Xcode 12, an integrated development software capable of verifying again the work and create a user interface (UI) for the application. Once the application is completed, it can be published and inserted into the appropriate devices.

For the "Interpretation Centre of the Lower Valdisieve" it was considered appropriate to use the *marker-based* technology: through the use of a *device* on which an *App* (Fig. 10) has been previously installed it is possible, defining maps, historical photographs, or physical models, to visualise the corresponding digital models that can be interrogated in all their aspects, thus allowing a *smart* use of the information obtained through historical, archaeological and morphometric analyses.

4. Documentation and enhancement of the ten panels of the Paradise Gates

In the fifth room, dedicated to the Gates of Paradise, the 3D prints of the ten panels (each measuring 80X80 cm, (Giusti, 2015) made by the master for the Baptistery of San Giovanni in Florence will be hosted, reproduced in plastic material on a scale of 1: 1 and without chromatic data. The copies, placed at such a height as to allow visitors to have an unprecedented tactile experience, will also allow the visually impaired to appreciate the numerous planes on which Ghiberti

depicted architecture, landscapes, animals and characters described in the stories of the prophets. Each panel will also function as a *target*, allowing a 3D animation to be activated on a *device* (a tablet free for visitors to use for the time of their visit or on personal mobile devices) that will project the user into the space represented by the master. The image framed by the camera will be progressively replaced by *frames* with the renderings of the 3D model of the panel with its apparent colour. The video sequences, created *ad hoc* in order to frame only the parts of the *mesh* that it has been possible to generate starting from the original representations, will allow us to describe in the right time sequence the multiple events that Ghiberti portrayed within the same panel, while providing an explanation, through a narrating voice, of the events themselves with reference to the biblical text.

Fig. 11: High-poly polygonal model of the tile with the Stories of Joseph.

4.1 Modelling and texturing operations

The working group was able to use the *high-poly* models of the panels made following the morphometric documentation made of them during the restoration operations (Giusti, 2015). The original model with The Stories of Joseph, for example, consists of 26,312,297 polygons with an average side length of 0.278 mm (file size 1.284 Gb) (Fig. 11).

To support the aims of the project it was necessary, for each panel and starting from their digital copy, to have 3D models both of the context in which the individual episodes take place, and of the characters and objects that populate it.

The elements useful for the recomposition of the three-dimensional scene have been divided up according to two distinct parameters, one linked to the role played in the narration of the biblical episodes, the other to the original spatial datum (i.e. their projection).

Once the groups were defined, each element was isolated from the others and from the base and subjected to an initial decimation process using the Geomagic software (reduction equal to 30% of the number of polygons) which also made it possible to generate isotropic surfaces (Fig. 12).

Subsequently, the individual components were imported into the Zbrush programme and subjected to a semiautomatic process of *retopology* through the "Zremesher"[16] function, which allowed us both to further reduce the number of polygons and to generate quad-dominant meshes, which generally provide better results when parameterising the models (Fig. 13).

In order to compensate for the loss of the geometric data and, consequently, also of the details impressed by the artist, we decided to rely on the U, V maps. In order to apply these maps, it was first necessary to proceed with the parameterisation of the *high-poly* models which was achieved using the "*autounwrap*" function of the Substance Painter programme, able to effectively combine speed of execution and quality of the result[17].

The maps used, in addition to that of the normals, such as the Ambient *occlusion map* and the *Curvature map*, were obtained through the "*Bake Mesh Map*" command of the same *software*[18].

[16] During this operation it was necessary to intervene on the following parameters: *DetectEdges* (automatically recognises the edges of the model in order to better preserve them), *Target Polygons Count* (allows you to define the number of polygons desired, in this case values between 30 and 50 have produced satisfactory results in terms of reduction of polygons and quality of the final geometry), *Adapt* (the option has been disabled), *Adaptive Size* (this function set to low values allows the generation of square rather than triangular polygons).

[17] The default parameters were found to be effective.

[18] 4k maps with default parameters have been generated, except for the number of *secondary rays* relating to the calculation of *ambient occlusion* and *curvature* which has been increased up to the maximum value. The orographic data is

Fig. 12: Lorenzo Ghiberti, Gates of Paradise, Stories of Jacob and Esau (medium-poly detail of a group of figures).

Fig. 13: Lorenzo Ghiberti, Gates of Paradise, Stories of Jacob and Esau (detail of the retopology of a group of figures).

In order not to introduce arbitrary components, it was preliminarily decided to leave the figures unchanged and therefore not to proceed with the reconstruction of the missing parts.

A different attitude was adopted instead towards those components that define the contexts (*scenes*), be they architecture (fifth, sixth and tenth picture) or hilly/mountain landscapes. In this case the presence of gaps would have frustrated any attempt to document the elements depicted by the master in a continuous three-dimensional space.

The architecture was completely reconstructed by direct modeling in a 3ds Max environment starting from the results of the perspective reconstruction (Fig. 14).

Hills and mountains, which Ghiberti represents in the form of more or less sloping rocky cliffs, were created through a manual *retopology* operation, again within 3ds Max, carefully following the profiles and angles, subsequently emphasised through the *displacement* and *turbosmooth* "modifiers".

To avoid generating, due to the effect of perspective, large areas that have not been described by the artist, the mountains placed in the background have been modelled using the same dimensions as they have in the panels; using this device it was possible to significantly reduce the distances between elements in the foreground and elements in the background (Fig. 15).

In each panel, characters, objects, plants and animals protrude from the plane to which they are anchored to differing degrees; some are barely engraved on the bronze plate while others are almost in full relief. Also in this case, where it was considered appropriate to bring out the details, the *displacement* maps were again used (Fig. 16).

As regards the *texturing* it was decided to resort to procedural maps. The Substance Painter programme made it possible in the first place to use a material, in the present case a metal, which simulates the mercury gilding imprinted on the panels, to which procedural maps were subsequently applied (*Grunge map*, *Scratches map*, etc.) which enabled the material to be customised by acting on the multiple parameters available.

Once the desired effect was achieved, the programme allowed us to export ad hoc 4K maps for Corona Renderer (*diffuse map*, *glossiness map*, *reflection map*, *height map*, *IOR map*) that were used to texturise the models. Given the large number of objects present in the same scene, the choice of this method allowed a simpler and more immediate control of the results obtained (Fig. 17).

present in all the panels except for the one with the meeting between Solomon and the Queen of Sheba.

Fig. 14: 3D Model of the scene of the tile with the Stories of Jacob and Esau.

Fig. 16: Render of the scene of the tile with the Stories of Jacob and Esau.

Fig. 15 Render of the scene of the tile with the Stories of Jacob and Esau.

Fig. 17: Render of the scene of the tile with the Stories of Jacob and Esau. Detail of Isaac and Jacob.

4.2 3D animation

The decision to leave the figures unchanged and, therefore, not to proceed with the reconstruction of the missing parts drastically limited the possibility of moving the camera at will within the three-dimensional space, binding it to predefined positions from which only the real elements modelled by the artist would be taken and concealing the previously described gaps from view at the same time.

On the basis of the *storyboard*, animated sequences were created that make it possible to explore the "landscape of art" depicted by Ghiberti.

An effective expedient to give greater dynamism to the scenes while remaining as faithful as possible to the artist's work, in addition to that of the small movements imprinted on the *meshes* through *rigging* techniques, is the

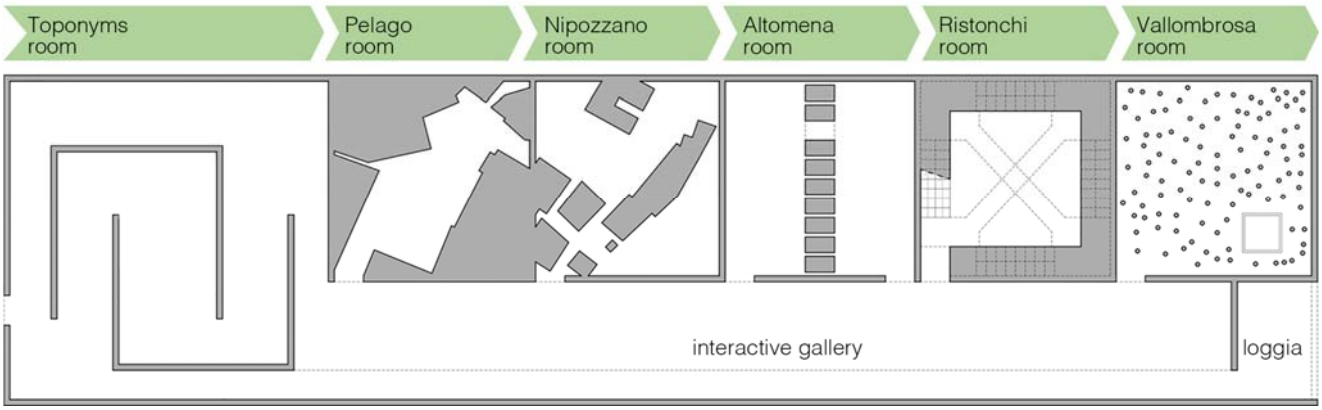

Fig. 18: Planimetric diagram of the operation of the virtual museum (author's diagram).

animation of portions of *texture* obtained from the high definition photographs of the panels. This expedient was particularly useful for simulating, for example, the motion of water; in this case a *noise* modifier, also animated, has been added to the animation of the *texture*, in order to simulate the flow of a stream.

5. Towards the opening of the Interpretation Centre

To meet the expectations that have arisen over time around the Ghibertian project and in order to introduce the contents of the Interpretation Centre to the public, a promotional video (visible at the web address https://www.youtube.com/watch?v=XS9nty3-ujE) and a virtual exhibition have been created.

The latter, in particular, was given the task of introducing the visitor to the themes related to the 'Lands of Ghiberti' through 3D animations, which will be implemented within a virtual tour and a video.

The originality of the experience consists in having made the (virtual) architecture designed *ad hoc* assume a pivotal role as a function of the information it must contain, thus allowing reflection on the design principles underlying it (Carlevaris, 2011).

The resulting spaces are imaginary, poetic and evocative and are placed on the margin between reality and dream, allowing an unconventional reading of the soul of the places.

The visit is conceived as in a conventional museum, through a series of rooms arranged following a central distribution system (Fig. 18). The museum, although it does not represent any specific place, maintains its truthfulness in the conservation of the founding rules of architecture, in its representation of environments that could actually exist. Within this "fantasy" envelope, the rooms are conceived as a personal interpretation of well-defined physical places, a distortion of reality to emphasise its particular characteristics.

The initial room is conceived as an entrance to the virtual world and is structured as an environment completely enveloped in a cartography of the territory, on which the most significant places are highlighted and illustrated and to which their own thematic room corresponds.

Walking through the room/map, visitors move in geographical space and in historical time, guided by the common thread of the toponymy which, through the story of a crystallised vision of the territory at the time of Ghiberti, allows them to recognise in the landscape the indelible traces of his past.

An interactive gallery gives access to five rooms (Pelago, Nipozzano, Altomena, Ristonchi and Vallombrosa), within which the architecture recreates evocative spaces able to recount the places by interpreting the peculiarities that distinguish them in the complexity of the territory.

A video is assigned the task of simulating the visitors' passage within the virtual environment by guiding them, providing them with a possible interpretation key, a suggestion, a privileged point of view.

The Pelago room recreates the urban void of the market square, reproducing its volumes and the inclination of the floor starting from an integrated relief of the existing one (Fig. 19). The interpretation and simplification of the built reality was aimed at emphasising the area of the square, a typical Late Medieval market, where the urban scenes were characterised by the presence

Fig. 19: Rendered model of the Pelago room.

Fig. 20: Rendered model of the Altomena room.

of numerous craftsmen's workshops, which constituted the distinctive feature of the centre.

Similarly, the room dedicated to Nipozzano evokes the theme of the village by reproducing its layout that winds its way beyond the walls of the castle and opens onto the valley with unprecedented glimpses of the residential buildings.

The Altomena room reconstructs the setting of the cellar of the villa-farm, leading on a journey through the wine production process that strongly characterises and identifies the landscape (Fig. 20). The dim light, the heat, the smell of the must are reinterpreted by an evocative architecture which, while remaining recognisable, introduces the user to the traditional processes of transformation of the raw materials of the territory.

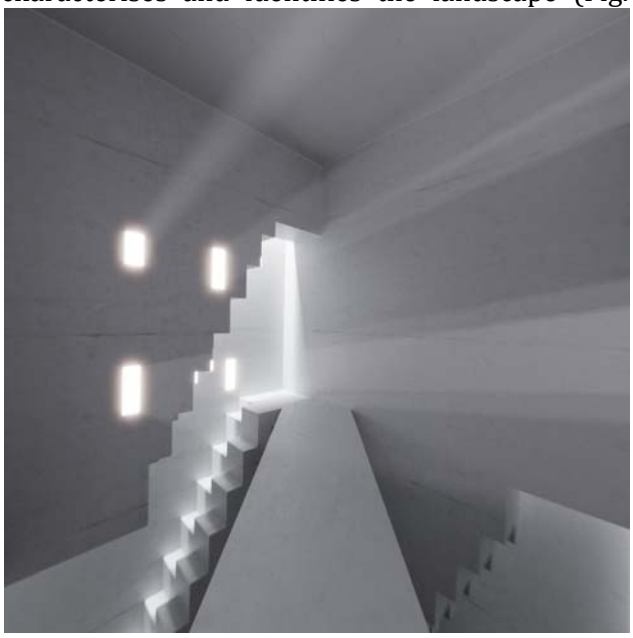

Fig. 21: Rendered model of the Ristonchi room.

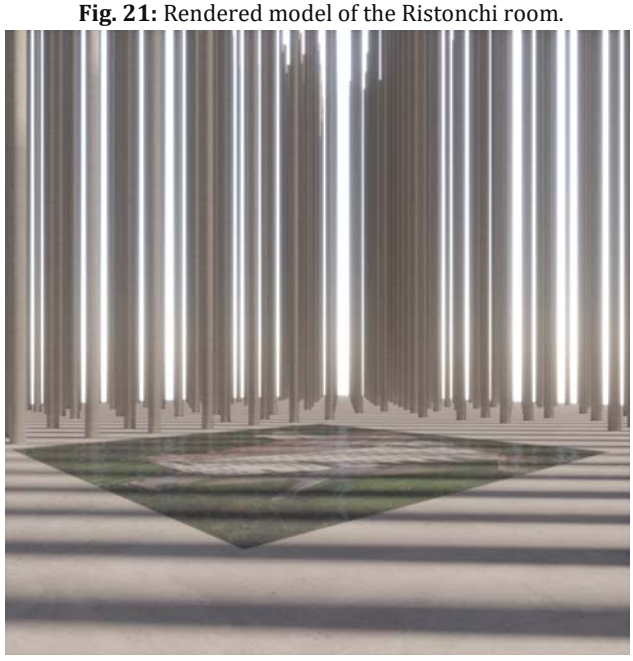

Fig. 22: Rendered model of the Vallombrosa room.

The many defensive structures that dot the lower Valdisieve are recalled to the eyes of the "visitor" in the Ristonchi room, in which a high tower is recreated and inside which you can climb steep stairs carved into the thickness of the

imposing walls, up to reach a central embrasure from which it is possible to appreciate the vastness of the territory controlled (Fig. 21).

Finally, the last room aims to recreate the sense of isolation and introspection that one feels when crossing the Vallombrosa forest to reach the monastery of the same name (Fig. 22). The light that filters with intermittent irregularity between the branches of the trees guides you on a path that seems to be lost among the trunks of the tall fir trees, until suddenly the imposing bulk of the abbey is reflected in the fish pond that faces it.

At the end of the itinerary, the distribution gallery ends with a loggia opening onto the Valdisieve landscape, which can be appreciated in its entirety without the limitations and filters present in the thematic rooms. At the end of the story, the interpretations introduced should probably enable the user to approach the territory in a more conscious and responsible way, as he will have acquired all the necessary information concerning its peculiarities. In other words, the virtual visitor should be able to approach the real places having now understood the complex historical-political structure linked to the presence of the Guidi castles and the fortification and control systems of the territory, the agrarian organisation strongly linked to the activities related to viticulture and olive growing, the strong link to the ancient trades that are still practiced today in towns and villages, the forest-wooded areas belonging to the Vallombrosa abbey.

6. Conclusions

Today's digital technologies make it possible to benefit from the cultural heritage in new forms that are closer to the expectations not only of the non-specialist public, but increasingly also of the professionals (Figs. 23-24). Having overcome the initial preconception, which for many years and in part still today has meant that the scientific value of these products was not recognised, there are many initiatives in all areas of research that encourage the use of virtual reality and its multiple declinations (AR, IR and MR) and uses (from 3D animation to multimedia applications). The indications expressed in the ministerial directives for 4.0 museums confirm the direction taken. In the humanistic field, *digital humanities* are now an established reality and a research field in continuous evolution; as in the case in question, digital technologies on the one hand open up new interpretative horizons, on the other hand their results can be profitably conveyed.

Figs. 23-24: Renders of the scenes of the tiles with the Stories of Creation and Abraham.

Attribution of paragraphs

Alessandro Merlo is the author of the paragraphs (1, 2, 2.1), Gaia Lavoratti is the author of the paragraphs (4, 5), Giulia Lazzari is the author of the paragraphs (3, 6), Alessandro Manghi is the author of the paragraph (3.1), Matteo Bartoli is the author of the paragraphs (4.1, 4.2).

REFERENCES

Agostino, D., & Arnaboldi, M. (2021). From preservation to entertainment: Accounting for the transformation of participation in Italian state museums. *Accounting History, 26(1)*, 102-122.

Alvaro-Tordesillas, A., Crespo-Aller, S., & Barba, S. (2019). Artalive: an android application for augmented reality without markers, based on anamorphic images. In D. Gonzalez-Aguilera, F. Remondino, I. Toschi, P. Rodriguez-Gonzalvez, & E. Stathopoulou (Eds.*), CIPA International Symposium "Documenting the past for a better future"* (pp. 71-76). Ávila, Spain: ISPRS, XLII-2/W15.

Apollonio, F.I., Ballabeni, M., & Gaiani, M. (2014). Color enhanced pipelines for reality-based 3D modeling of on site medium sized archeological artifacts. *Virtual Archaeology Review, 5(10)*, 59-76.

Apollonio, F.I., Fantini, F., Garagnani, S., & Gaiani, M. (2021). A Photogrammetry-Based Workflow for the Accurate 3D Construccion and Visualization of Museum Assets. *Remote Sensing, 2021(13)*, 18-24.

Apollonio, F.I., Gaiani, M., Basilissi, W., & Rivaroli, L. (2017). Photogrammetry driven tools to support the restoration of open-air bronze surfaces of sculptures: an integrated solution starting from the experience of the Neptune Fountain in Bologna. *Remote Sensing, 2017(42)*, 47-54.

Becattini, M., & Granchi, A. (1985). *Alto Mugello, Mugello, Val di Sieve: itinerario nel patrimonio storico-artistico*. Firenze, Italy: Giorgi & Gambi.

Berthelot, M., Nony, N., Gugi, L., Bishop, A., & De Luca, L. (2015). The Avignon Bridge: a 3D reconstruction project integrating archaeological, historical and geomorphological issues. *Remote Sensing, 2015(40)*, 223-227.

Bianchini, C. (2014). Survey, modeling, interpretation as multidisciplinary components of a knowledge system. *SCIRES-IT - SCIentific RESearch and Information Technology, 4(1)*, 15-24.

Bicchierai, M. (2005). La signoria dei conti Guidi in Valdarno. Osservazioni ed ipotesi. In G. Pinto & P. Pirillo (Eds.), *Lontano dalle città. Il Valdarno di Sopra nei secoli XII-XIII. Atti del Convegno (Figline Valdarno – Montevarchi, 9-11 novembre 2001)* (pp. 83-116). Roma, Italy: Viella.

Bonaccini, E. (2013). *La valorizzazione digitale del patrimonio culturale in Europa e in Italia. Forme di fruizione e di valorizzazione museale attraverso le nuove tecnologie e i social media. Una proposta di turismo wireless per Catania*. Tesi di dottorato. Università degli Studi di Catania.

Bordoni, L., & Pierattini, S. (2011). Esperienze di fruizione virtuale del patrimonio archeologico. In S. Gianolio (Ed.), *Archeologia virtuale. La metodologia prima del software. Atti del II seminario (Roma, 5-6 aprile 2011)* (pp. 116-130). Roma, Italy: Esperia.

Brusaporci, S., & Trizio, I. (2013). La "Carta di Londra" e il patrimonio architettonico: riflessioni circa una possibile implementazione. *SCIRES-IT - SCIentific RESearch and Information Technology, 3(2)*, 55-68.

Buonamici, F., et al. (2017). Reverse engineering modeling methods and tools: a survey. *Computer-Aided Design and Applications, 15*, 1-22.

Carlevaris, L. (2011). Luce, superficie, visione: il modello come metafora. In P. Albisinni & L. De Carlo (Eds.), *Architettura | di-segno | modello. Verso un archivio digitale dell'opera di maestri del XX secolo* (pp. 97-108). Roma, Italy: Gangemi.

Caudullo, T. (2020). Scansione laser 3D. tecnologia al servizio della tutela dei beni culturali. *Archeomatica, 3/4*, 6-9.

Cherubini, G. (2009). Paesaggi, genti, poteri, economia del Casentino negli ultimi secoli del Medioevo. *Rivista di storia dell'agricoltura, 49(1)*, 35-57.

Chuah, S.H-W. (2019). Wearable XR-technology: literature review, conceptual framework and future research directions. *International Journal of Technology Marketing, 13(3/4)*, 205-259.

Ciardi Duprè Dal Poggetto, M.G. (1978). Porta del Paradiso. Introduzione. In AA.VV., *Lorenzo Ghiberti. Materia e Ragionamenti* (pp. 330-332). Firenze, Italy: Centro Di.

Clini, P., Nespeca, R., & Crinelli, G. (2017). Il Distretto Culturale Evoluto Flaminia Nextore. Innovazione digitale nel nuovo museo virtuale della via Flaminia a Fano. In A. di Luggo, P. Giordano, R. Florio, L.M. Papa, A. Rossi, O. Zerlenga, S. Barba, M. Campi & A. Cirafici (Eds.), *Territori e frontiere della Rappresentazione / Territories and frontiers of Representation* (pp. 821-828). Roma, Italy: Gangemi.

Clini, P. (Ed.) (2011). *Documentare l'architettura storica: analisi, rilievo e progetto*. Roma, Italy: Aracne.

Colombo, M.E. (2020). *Musei e cultura digitale. Fra narrativa, pratiche e testimonianze*. Milano, Italy: Editrice Bibliografica.

Commissione Tecnologie Digitali per il Patrimonio Culturale di ICOM Italia (2020). *Glossario Digitale e Tecnologie.*

Gabellone, F. (2012). La trasparenza scientifica in archeologia virtuale: una lettura critica al principio n.7 della Carta di Siviglia. *SCIRES-IT - SCIentific RESearch and Information Technology, 2(2)*, 99-123.

Gabellone, F. (2019). *Archeologia Virtuale. Teoria, tecnica e casi studio*. Lecce, Italy: Grifo.

Giusti, A. (Ed.) (2015), *Il Paradiso ritrovato. Il restauro della Porta del Ghiberti*. Firenze, Italy: Mandragore.

Giusti, A., & Radke, G.M. (2012). *La porta del Paradiso. Dalla bottega di Lorenzo Ghiberti al cantiere di restauro*. Firenze, Italy: Giunti.

Guidi, G., & Angheleddu, D. (2016). Displacement Mapping as a Metric Tool for Optimizing Mesh Models Originated by 3D Digitization. *Journal on Computing and Cultural Heritage, 9*, 1-23.

ICRC Innovation Board (2018). *Extended Reality. Determining needs, expectations and the future of XR for the ICRC*. Retrieved from https://blogs.icrc.org/inspired/wp-content/uploads/sites/107/2019/10/Extended-Reality-Report-BRIEF.pdf .

Krautheimer, R., & Krautheimer-Hess, T. (1970). *Lorenzo Ghiberti*. Princeton, NJ: Princeton University press.

La Carta di Londra (2009). Retrieved from http://www.londoncharter.org/.

Lupo, E., & Özdil, E. (2013). Towards a "Smart Heritage" as Future Diffused Museums: Design and Communication Technologies to Innovate the Experience of the Cultural Patrimony in Smart Cities. *Int. J. Incl. Mus., 2013(6)*, 159-169.

Mandarano, N. (2019). *Musei e media digitali*. Roma, Italy: Carocci.

Merlo, A., Vendrell-Vidal, E., Fantini, F., & Sanchez-Belenguer, C. (2012). The mayan mascaron from Chilonché (Péten, Giatemala): new techologies for cultural heritage dissemination. In AA.VV., *Proceeding of CHNT 17*. Wien, Austria: Museen der Stadt Wien – Stadtarchaologie.

Merlo, A., et al. (2015). The fortified settlement of Bivignano. Computer graphic tools in analysis and its representation. In AA.VV., *Proceeding of CHNT 19*. Wien, Austria: Museen der Stadt Wien – Stadtarchaologie.

Merlo, A. (2019). ICT e cultural heritage: il video "La Battaglia di Anghiari di Leonardo da Vinci. Storia di un capolavoro incompiuto". Premesse metodologiche. In E. Ferretti, A. Merlo & S. Pini, *Dalla storia al museo: la Battaglia d'Anghiari di Leonardo da Vinci. Temi e problemi fra architettura, ricostruzioni virtuali e disseminazione della ricerca scientifica*. Firenze, Italy: didapress.

Merlo, A., & Lavoratti, G. (2020). Ghibertiana. Documentazione e valorizzazione dell'opera di Lorenzo Ghiberti. In P. Belardi (Ed.), *Riflessioni. L'Arte del Disegno/il Disegno dell'Arte* (pp. 817-824). Roma, Italy: Gangemi.

MiBAC (2019). *Piano triennale per la Digitalizzazione e l'Innovazione dei Musei. DG-MU 19.07.2019 n. 892*. Retrieved from http://musei.beniculturali.it/wp-content/uploads/2019/08/Piano-Triennale-per-la-Digitalizzazione-e-l%E2%80%99Innovazione-dei-Musei.pdf .

Minto, S. (2013). *PointCloud2Publish. Visualizzazione e condivisione online di modelli 3D.* Tesi del master Open Téchne. Trento, Italy: Fondazione Bruno Kessler.

Mori, L. (2012). Serious games e simulazione come risorse per l'educazione. *META: Research in Hermeneutics, Phenomenology, and Practical Philosophy, IV (1)*, 56-72.

Pan, R., et al. (2017). Normals and texture fusion for enhancing orthogonal projections of 3D models. *Journal of Cultural Heritage, 23*, 33-39.

Principi di Siviglia (2011). Retrieved from http://sevilleprinciples.com/.

Rauty, N. (2003). *Documenti per la storia dei conti Guidi in Toscana. Le origini e i primi secoli 887-1164*. Firenze, Itay: Olschki.

Remondino, F. (2004). From point cloud to surface: modelling and visualization problem. In A. Gruen, Sh. Murai, J. Niederoest & F. Remondino (Eds.), *Visualization and Animation of Reality-based 3D Models (24-28 February 2003)* (pp. 1-11). Tarasp-Vulpera, Switzerland: ISPRS, WG V/6.

Ruggeri, D. (2019). *Il facsimile digitale come strumento di interazione culturale. Realtà aumentata e virtuale per una fruizione immersiva e interattiva del Cultural Heritage*. Tesi di Dottorato in Scienze dell'Ingegneria – Curriculum in Ingegneria Civile, Ambientale, Edile e Architettura. Università Politecnica delle Marche.

Russo, M., & Guidi, G. (2011). Reality-based and reconstructive models: digital media for cultural heritage valorization. *SCIRES-IT - SCIentific RESearch and Information Technology, I (2)*, 71-86.

Salvestrini, F. (2009). I conti Guidi e il monachesimo vallombrosano. In F. Canaccini (Ed.), *La lunga storia di una stirpe comitale. I conti Guidi tra Romagna e Toscana. Atti del convegno. Modigliana–Poppi, 28-31 agosto 2003* (pp. 291-315). Firenze, Italy: Olschki.

Vannini, G., & Molducci, C. (2009). I castelli dei Guidi fra Romagna e Toscana: i casi di Modigliana e Romena; un progetto di archeologia territoriale. In F. Canaccini (Ed.), *La lunga storia di una stirpe comitale. I conti Guidi tra Romagna e Toscana. Atti del convegno. Modigliana–Poppi, 28-31 agosto 2003* (pp. 177-210). Firenze, Italy: Olschki.

Verhoeven, G. (2017). Computer graphics meets image fusion: the power of texture baking to simultaneously visualise 3D surface features and colour. In J. Hayes, C. Ouimet, M. Santana Quintero, S. Fai & L. Smith (Eds.), *ICOMOS/ISPRS International Scientific Committee on Heritage Documentation (CIPA) 26th International CIPA Symposium – Digital Workflows for Heritage Conservation (28 August – 1 September 2017)* (pp. 195-302). Ottawa, Canada: ISPRS, IV-2W2.