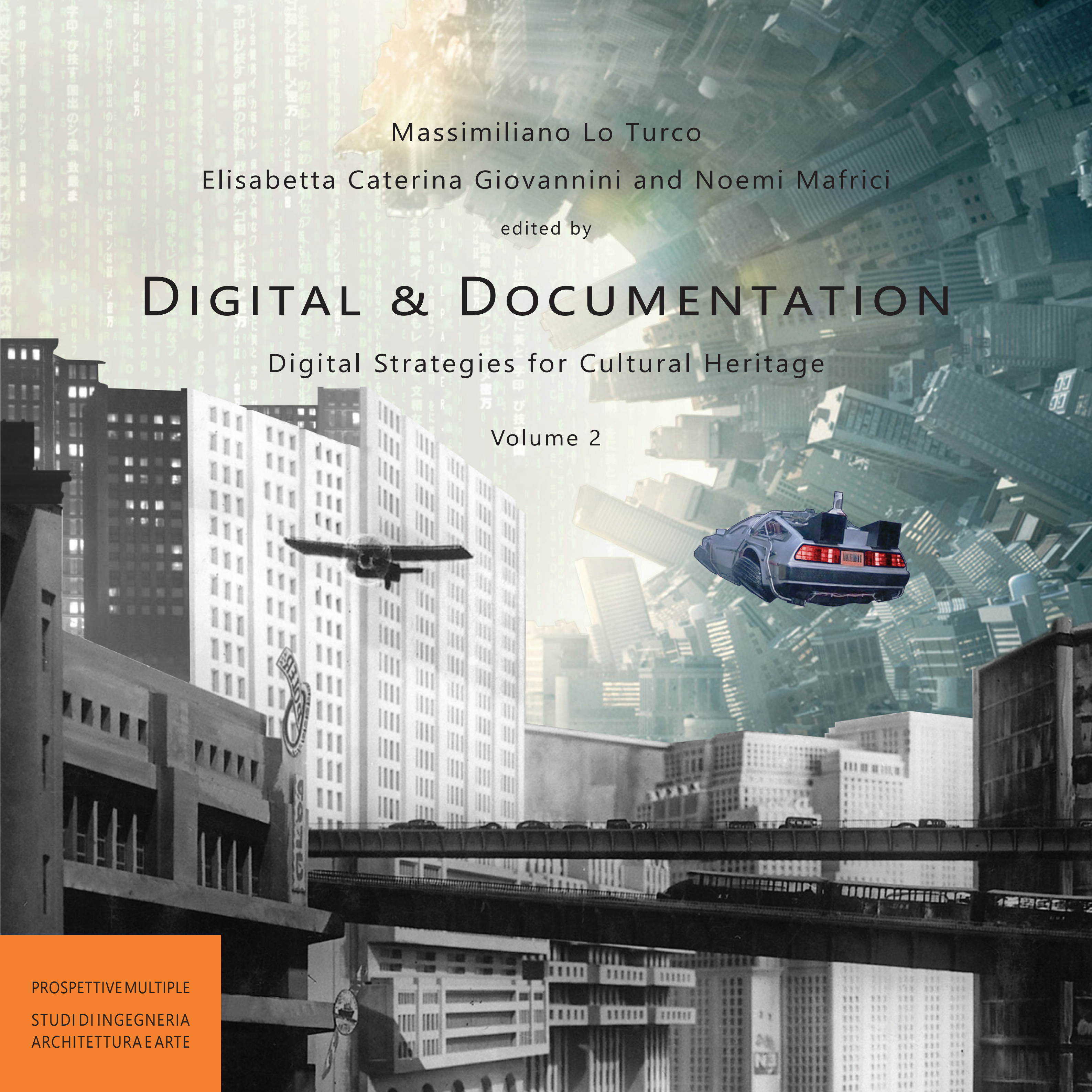

Massimiliano Lo Turco

Elisabetta Caterina Giovannini and Noemi Mafrici

edited by

DIGITAL & DOCUMENTATION

Digital Strategies for Cultural Heritage

Volume 2

PROSPETTIVE MULTIPLE

STUDI DI INGEGNERIA ARCHITETTURA E ARTE

Massimiliano Lo Turco

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Digital strategies for Cultural Heritage

Volume 2

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The volume consists of a collection of contributions from the seminar "Digital & Documentation: Digital Strategies fo Cultural Heritage", realised at the Politecnico di Torino on June 14th, 2019. The event, organized by the "BIM Acquisition as Cultural Key TO Transfer Heritage of ancient Egypt For many Uses To many Users REplayed" - B.A.C.K. TO T.H.E. F.U.T.U.RE. Project - team of DAD - Department of Architecture and Design of Politecnico di Torino, promotes the themes of digital modeling and virtual environments applied to the documentation of architectural scenarios and the implementation of museum complexes through communication programs of immersive fruition.
The event has provide the contribution of external experts and lecturers in the field of digital documentation for Cultural Heritage. The scientific responsible for the organization of the event is Prof. Massimiliano Lo Turco, Politecnico di Torino.

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The event "Digital & Documentation - Vol. 2" has seen the participation of professors, researchers, scholars and private institutions

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Un oggetto può dirsi culturale nella misura in cui resiste nel tempo

Hannah Arendt, 1961

Christian Greco

Director of Fondazione Museo delle Antichità Egizie di Torino

Director of Museo Egizio of Turin since 2014, he led the redevelopment project and renovated the museum of antiquities into an archaeological museum in 2015. He built significant international collaborations with museums, universities and research institutes and he is involved in courses of material culture of Ancient Egypt and museology at Università di Torino, Università di Pavia, Scuola di Specializzazione in Beni Archeologici of the Università Cattolica del Sacro Cuore di Milano, IUSS of Pavia, thanks to his passion for teaching. He is lecturer in several masters in museum communication and management, bringing his knowledge as researcher and museum expert. Among his remarkable archaeological field activities, he was member of the Epigraphic Survey of the Oriental Institute of the University of Chicago in Luxor and he is co-director of the Italian-Dutch archaeological expedition in Saqqara from 2011.

MUSEUMS AND RESEARCH

Foreword

Research teaches us to constantly question our results in an attempt to understand the ancient world thoroughly and to understaWnd more about ourselves.
The study of a past civilization in depth entails the analysis of historical events, the interpretation of written sources and archaeological data, a study of the society, of the economic, social and political organisation, administration, the evolution of thought, theology and rituality bound up with the cult of the supernatural, conceptions of life after death and considerations on the transience of human existence. Archaeology has brought to light settlements that allow us to discover human activities from thousands of years ago.
We are all indebWted to this past history and one outcome of it. Our own biological structure, our technology, the structure of society and contemporary culture, even our cognitive method and our psychology, derive from the past. Historical awareness and the study of ancient civilisations are therefore essential to understanding our role in the present.
Today we find ourselves immersed in the so-called digital revolution that has already profoundly transformed our cognitive approach and the way we work. In the archaeological field, photogrammetry and 3D modelling enable archaeologists to document the whole excavation process and to reconstruct contexts even after their removal. We can reproduce a sarcophagus with sub-millimetric precision, recording all the phases of its production and reuse. Non-invasive diagnostic imaging allows us to peer into a still-sealed vessel and virtually unwrap mummies. Detailed analyses now give scholars the opportunity to observe the fibres of a papyrus, facilitating the reconstruction of ancient documents. Digital communication also enables us to create virtual work environments in which scholars from around the world can work together and compare their data. All this facilitates and accelerates the work of the philologist. So does this mean that the role of the humanist's role is becoming subordinate? Quite the contrary. The data supplied to us is ever more detailed and complex and requires an even more profound level of interpretation.
The scientist and the humanist must increasingly work closely together to try to unravel the complexity of the contemporary world. An ever more profound collaboration that goes beyond the dogmatism of individual fields of knowledge, with the definition of a shared semantics and the development of a true multidisciplinary approach are the only method we have to cope with the challenges of the future. And in this, what will the museum's role be? Are these institutions destined to disappear?
We must not forget that in rethinking the role that museums can have in the future we must at the same time remember the main reason why they were founded, namely to be the place where objects from the past could

be preserved. And, despite all the changes we have gone through, it is undeniable that the core of the museum experience is still that of being before artistic products, archaeological documents or the records of social history. The changes will continue.
We will devise different organisational and architectural solutions that will respond more fully to contemporary needs. There will certainly also be new forms of cultural consumption. Our task will always remain, however, to improve the visual, aesthetic and intellectual experience of every visitor before an artefact from the past, seeking to provide all the information necessary to enrich the comprehension of it. The future of museums is, as it has always been, research.

Christian Greco

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Sandro Parrinello

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Associate Professor of University of Pavia, European Research Ph.D. in Representation and Survey Sciences.
Since 2012, he is Visiting Professor at Perm National Research Polytechnic University (Russia) and in 2015 he receives an honorary degree from the State Academy of Civil Engineering and Architecture of Odessa (Ukraine). Since 2005, he is an expert of UNESCO; in 2011 he was appointed Expert and Voting member in ICOFORT as contact person for Italy.
He is director of DAda Lab. - Drawing Architecture Document Action Laboratory of University of Pavia, and director of Joint LS3D Landscape Survey & Design laboratory of University of Florence and University of Pavia.

DRAWINGS UPDATING AND LANGUAGES REWRITING FOR THE STRUCTURING OF KNOWLEDGE

Presentation

The evolution of writing systems for the description of the features that animate the cultural context of a certain society is a natural process that has always characterized the history of mankind. The awareness on what has led a given system to be what it is, and therefore to be understood and structured through a certain language, matures through the reading of these writings. In this sense, the updating of these languages is an expression of the constant change between the different generations that over time follow each other in a specific environment.
Thus, certain products of culture are described and re-described many times, even emphasizing different aspects from different angles or points of view, and over time such minor variations can produce significant changes in the identity of what is described and what can be understood.
The desire to perpetuate a message over time is not sufficient. The forms of communication change and even the simplest messages can become incomprehensible after a few centuries. The uncertainty about the persistence of a given language is to be added to that concerning the medium on which this language resides. It is not just a problem of symbols and the ability to decipher their meaning, it is equally important that such writing or drawing resides on a holder that can guarantee their durability over time.
From the oral narrative handed down from generation to generation to the written text, the uncertainty in being able to preserve a certain language and a certain message over time drove mankind to numerous efforts such as libraries and archives, which however were still not capable of saving numerous fragments of history from the inevitable process of decay and loss. For many reasons the language of the past crumbles with time and this loss of data leads to a simplification of knowledge in a synthesis that ends up transforming and dissolving in the language of the present. Today, at the dawn of the digital age, we may see a reflection of the same anxiety of the Neolithic man in handing over his memory from an oral narrative to the written word. In this passage from one form of knowledge transmission to another, in this remodulation of language from analogue to digital, we find the opportunity to carry out the reflections necessary for a renewal of the consciousness on knowledge. Moreover, it is precisely in this process of rewriting that lies the foundation of drawing and of all those arts in general whose purpose is to communicate with the purpose of addressing their expressive language, and the content that in such language resides, to an audience that could perpetuate them over time.
The Western conscience has for centuries turned its foundation on a language constructed by images and on a descriptive process based on the representation of what appears. As in response to this collective need, the image acquisition and elaboration techniques, among which the drawing certainly inserts, are today aimed at the structuring of that image, attributable to a landscape, capable of representing the complexity of our days.
This is the reason why digital technology has not largely distorted the concepts of representation, while it has profoundly changed

its languages, producing new image configurations resulted in a complete revolution of the paradigm of representation. What had been documented, described, drawn, is today again processed through image transformation processes that reconfigure models in a digital environment and structure a new language, capable of influencing the landscape of those tools we have historically learned to rely on. The broad issue of digital documentation concerns then the processes of a reconfiguration of knowledge, models of analysis, the shape and the image in general, to produce documentation systems, databases or whatever is necessary to preserve and transmit a certain knowledge.

It is not uncommon that digital surveys are requested for buildings or monumental complexes in spite of the existence of recent reliefs executed however not many years ago. The new drawings add another level to the stratification of knowledge processes and reveal a very different attitude, almost to the point of not resembling the previous ones. These drawings are oriented to describe an imperfection, a mimesis of the real in an attempt to describe the uniqueness of the architectural object, both concerning the constructive aspects and the various modifications that it has undergone over time. We have moved from a system-formal conception, which revealed a desire to typify the phenomena to optimize the management of the necessary data, to an overabundance of information. On one hand, this change harms the critical contribution of the draftsman, on the other it opens the way to fundamental readings and approaches necessary to reveal a renewed hyper-real expression of the representation and amplify the possibilities of interaction with the design.

For some time now more and more performing databases duplicate the image of the reality, giving life to increasingly complex digital organisms and structures. Precisely starting from this complexity and the possibility of a more and more precise approximation of the data and the measure, a duplicate of the real is generated. The representation, through drawing and digital relief, produces works in which the shapes and spaces of reality can find a new life, a second life, with a different opportunity to last. The numerous researches on these representations produce models and systems that constantly interact with the real, through 3D prints, prototypes, light projections and what is necessary to favour an ever easier interaction with the digital space. The interaction with the digital work is structured through constraints and projection tools in which drawings, models or more generally information become signals as fragments of a complex experience. Augmented, virtual and mixed realities are expressions of an interaction with a drawing that is, in turn, a digital landscape structure with no apparent boundaries. In this digital space, places are characterized by very specific, punctual and discrete information. The process of qualification of knowledge then becomes even more relevant if we consider how these tools intervene on the conditioning of the nervous system and our way of understanding and seeing the “real” dimension. The digital documentation becomes an opportunity to pause to see in a more specific way certain complexities that through analogical drawing are not able to emerge due to the approximation and overlapping of data.

In the digital space, the elements that constitute the datum are stratified according to structures that can, in turn, be drawn, which implies that there are possibilities to explain relationships otherwise difficult to describe.
The updating of the drawings therefore entails the rewriting of the languages, the translation of the headwords, the recoding of the words of the graphic text, arriving at reproductions that reveal attributes otherwise not always available. The simple possibility of “turning on” or “turning off” some levels, making portions of information visible with specific wills or commands allows the creation of actual time machines. With these, the user of the drawing can come into contact with different portions of buildings that describe one of its specific temporal conditions. Similarly, the available information can be governed by different access channels: this allows the same drawing to attract several different users, communicating different languages and trying to meet the expectations of the individual user. Web search engines are increasingly directing offers, creating more limited scenarios in which the user finds himself surrounded by a familiar environment. In this sense, even the transfer of knowledge can find forms of communication that aim at satisfying the expectations of those who use the product. In this sense, it is not just the product or the draughtsman to communicate with the public, but also the public to communicate its expectations to the product. The object and the user know each other simultaneously, creating a drawing that depicts the moving knowledge of a system of people composed of several different societies.
However, the dystopian atmospheres of this panorama have developed for some time and the drawing reconfiguration in the digital environment has already founded digital documentation models that are widely consolidated in the scientific community. In the second meeting of these days we give substance to the goal for numerous research activities, aimed at documenting the heritage, to increasingly go in the direction of a conscious development of multimedia products, with the intent to promote knowledge of artworks. What appears insistently and in a non-obvious way is that the product of digital reproduction can sometimes exceed the expected interest of the original one. Digital expressions have a dignity themselves because they are able to reach the interests of people more easily and to fascinate because they are capable to let people dream of a digital world where the great chaos of knowledge manages to find an order. If on one hand, the models of Egyptian tombs are rewritten and re-studied, renewing an analysis that can thus be more than a compilation, on the other hand, the projection of invisible archaeology testifies to the ephemeral and immaterial value of the digital that is projected beyond the limits of physical reproduction. The semantisation of the models, according to a standardization of the input values coming from a digital survey, also confirms how the language of these paths is being structured by complex alphabets from which it is possible to reconfigure new images and new reflections on the design of Cultural Heritage.

Sandro Parrinello

Massimiliano Lo Turco

Politecnico di Torino

Ph.D., Associate Professor ICAR/17 at the Department of Architcture and Design (DAD) of Politecnico di Torino. He conducts researchs in the field of digital architecture survey and modeling. He has been dealing for years in analyzing the capabilities of Building Information Modeling and Visual Programming Language applied to Cultural Heritage.

Principal Investigator of the BACK TO THE FUTURE's project, developed together with the Museo of Antichità Egizie di Torino. Program Director of the Bachelor's Degree in Architettura/ Architecture of Politecnico di Torino since 2018.

DIGITAL RESOURCES AS OPEN ACCESS TO HIDDEN CULTURAL HERITAGE COLLECTIONS

Preface

Once upon a time...the story started in December 2016, following an original idea of Prof. Rosa Tamborrino: we went with some students to visit the Egyptian Museum of Turin to conduct a didactic experience using some Egyptian temples in Nubia as case studies. It was unusual that the School of Architecture of the Politecnico di Torino dealt with the cultural heritage of ancient Egypt.

The teaching experience, although linked to the course of the Master's Degree in Architecture for Heritage preservation and enhancement was also quite unusual because we were all professors of a Polytechnic school, consequently, we lacked a set of historical and humanistic skills to work with specific expertise on these issues.

The topic covered the international campaign for the protection of the sites and monuments of Nubia, promoted by UNESCO. It is a virtuous example of solidarity and international cooperation in the cultural field for the preservation of the common heritage (this year marks the 60th anniversary). It has been conducted through the delicate operation of disassembly and reassembly of most of the temples in areas which are safe from the flooding of the Nile. Notably, Italy also took part in the campaign and received the temple of Ellesyia as a gift, which is still kept in the rooms of the Egyptian Museum. I remember the beautiful lectio of the Director of the Museum, Dr. Christian Greco and the subsequent guided tour organized by the curator, Dr. Alessia Fassone.

But the glimmer didn't come from seeing the real temple received as a gift, but from observing a small case on the right, containing a part of the collection of nineteenth-century wooden models of some Nubian temples. My first thought was the digitization of the physical models, considering the possibility of comparing the graphic elaborations of the surveys and the drawings/paintings of travellers through critical comparisons between different types of representation. When I enquired about the location of the remaining physical models, I received a simple and unsettling answer at the same time: "They are stored in the depots".

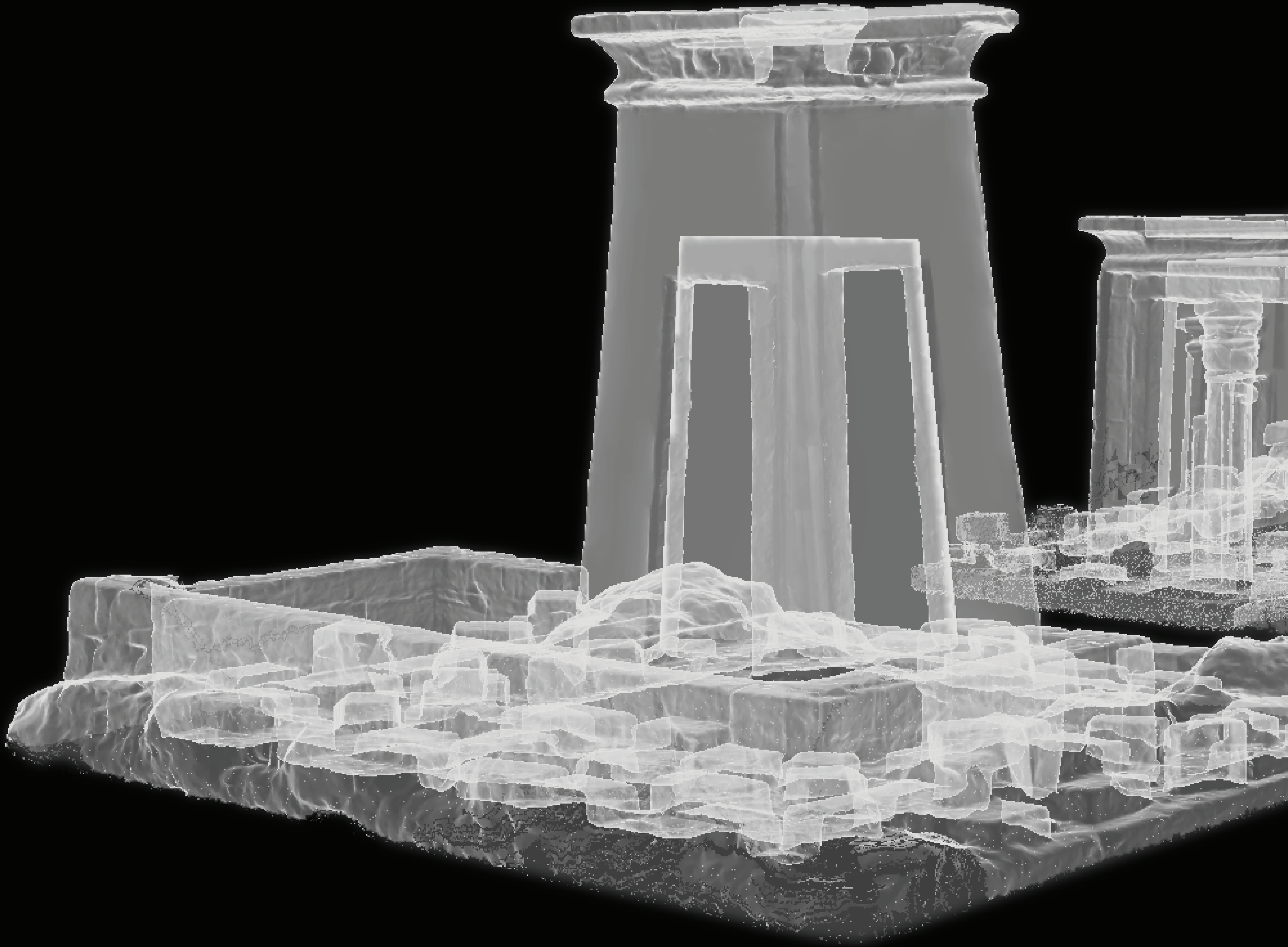
"*An idea is like a virus. Once it is implanted in the mind it continues to grow...*" citing one of the famous lines from Christopher Nolan's Inception films that inspired the graphic design of the cover of this volume and which, ironically, is also the title of a beautiful European project brilliantly described by a friend and colleague, Prof. Federica Maietti.

An article published in La Stampa at the end of May was entitled: "Seven out of ten masterpieces are hidden in the storage of the museums". The proportion is critical. The interesting article by Nicola Pinna warns against confusing museum deposits with cemeteries of culture, to use the words of Dr. Luciana Gerolami, assistant to the curator of the Castello Sforzesco in Milan. "The best comparison is with the management of a hospital, where the artworks are treated and preserved with great care," points out Dr. Gerolami. Unfortunately, however, it is important to remember that there are also many terminally ill people and even mass graves. The same article also mentions a project promoted by the Italian Ministry

of Cultural Heritage, which I find extremely interesting and stimulating, starting with its name, *Sleeping Beauty*. This is a classification work aimed at civic museums with the ambition of setting up a database of an important selection of works that do not find space in the exhibition areas accessible to the public.
Unfortunately, as often happens, the investigators have been confronted with the critical issues related to the disclosure of a database of materials that has been prepared with great effort. It is also worth mentioning the experience of the museum of Naples Capodimonte, with the original exhibition, also with a particularly evocative title: "Stories still to be written". More than a thousand works are shown, including paintings, statues, tapestries, porcelain, weapons and decorative arts objects belonging to the five Capodimonte deposits. The exhibition has been extended for four months, proving
Although in a different form and certainly less ambitious, the B.A.C.K. TO. T.H.E. F.U.T.U.RE. project (BIM Acquisition as Cultural Key TO Transfer Heritage of ancient Egypt For many Uses To many Users REplayed) also tries to answer these questions. The final outcome of the processes of digitization and research on the collections will be given to the Fondazione Museo delle Antichità Egizie to set up digital spaces for their future remote users. It is not in this phase that the project stands out for its innovative contribution to research. It is worth remembering that part of the objectives for the improvement were already described in the Ministerial Decree of February, the 21st, 2018 "Adoption of minimum uniform levels of quality for museums and places of public culture and activation of the National Museum System", which requires compliance with minimum standards for the correct organization of deposits referring to simple rules for sorting and storage of artworks not exhibited, according to criteria of functionality and security.
The same document also indicates specific objectives for improvement: the deposit of not displayed assets, ordered, could be made available for consultation on request and be used by the public at special events. The innovation of B.A.C.K. TO. T.H.E. F.U.T.U.RE. consists in the close relationship between a strong need for documentation and research on some still little studied objects and the complementary need to combine different types of knowledge, from the most formal to the most content related aspects, which enable the implementation of Digital Strategies for Cultural Heritage. This issue has to be considered a unifying element of the second volume of Digital & Documentation, albeit with very different variations.
The chapters of the volume are divided into three thematic parts: the first, entitled "Digital & Physical Models", collects the research experiences of the project I have had the pleasure to coordinate and carry out in collaboration with the Fondazione Museo delle Antichità Egizie of Turin.
The pilot initiative "*Create a network around your research idea*" is funded through a collaboration between Politecnico di Torino and Compagnia di San Paolo. The initiative is aimed at facilitating synergies among universities, companies and other entities of the socio-economic system for cooperative, multidisciplinary and innovative research projects. The

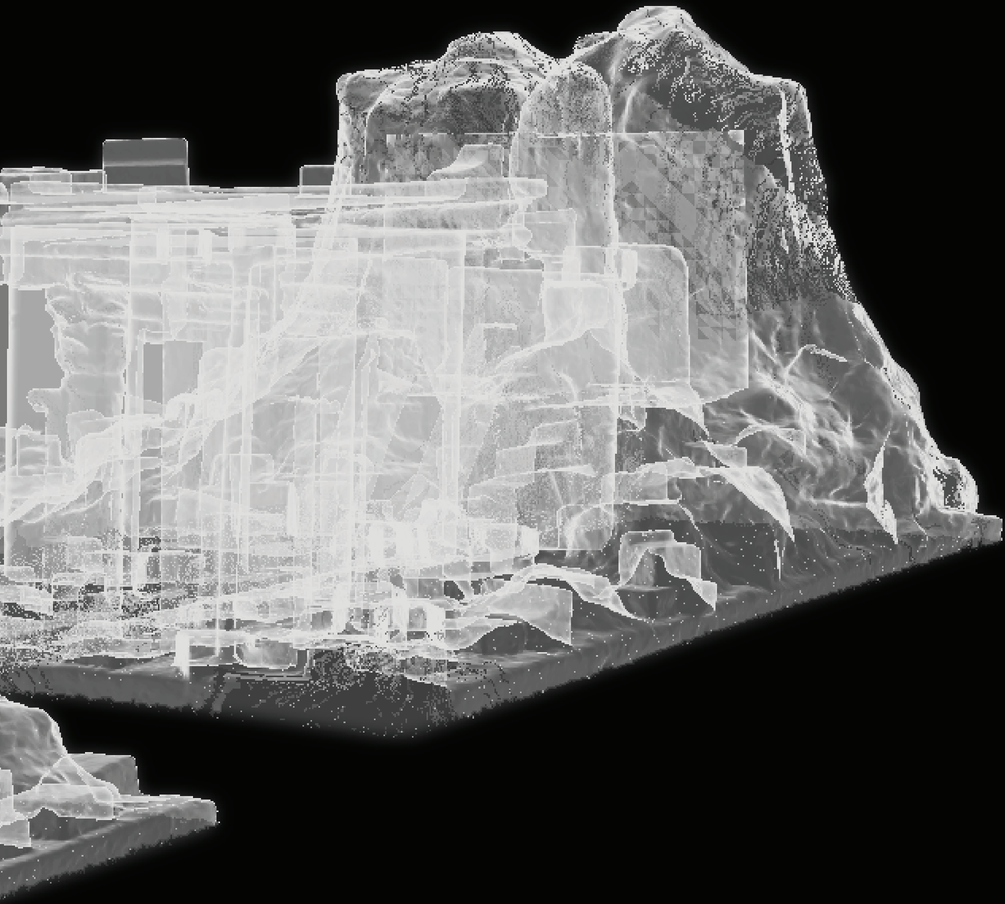
academic partner is the Professor Diego González Aguilera, Head of the Department of Cartographic and Field Engineering at the University of Salamanca. He is also Head of the TIDOP (The Geomatic Technologies for the 3D digitalization and modelling of complex objects). His support was crucial for commenting and discussing the 3D metric survey techniques, which are the most suitable to record small objects and their correct use and interpretation during the modeling steps.
The second part, entitled "*Databases, semantics & interoperability*", presents a selection of experiences, also of international standing, whose central theme is documentation: databases, classified and structured through ontologies, sharing of information using different interoperable platforms, automatic recognition of architectural objects through machine learning techniques.
In the third part, "*Digital Representations for Knowledge, Enhancement & Communication of Cultural Heritage*" the Digital Representation is at the centre of the debate, investigated in its multiple forms: from the most theoretical and research uses, to the most popular and also promotional ones, presented through critical and updated readings connected to new digital procedures for Cultural Heritage.
The book highlights the strong experimental value that leads to the conception of procedural prototypes. For the future editions, we hope that this richness will be implemented and replicated for different, and as yet unexplored cultural contents.

Massimiliano Lo Turco



PART I

DIGITAL & PHYSICAL MODELS



Fulvio Rinaudo is a full professor of Geomatics at the Department of Architecture and Design (Politecnico di Torino). Graduated in Civil Engineering, he received his Ph.D. in Geodetic and Cartographic Sciences in 1990. Author of more than 280 scientific papers, his research activity is mainly oriented to the applications of photogrammetry and scanner systems, GIS and HBIM design with particular attention to Cultural Heritage assets. Since 2005 he is active member of CIPA-HD (ICOMOS Int. Sc. Comm. for Cultural Heritage Documentation), and since 2008 chair of the "Data Acquisition and Processing in Cultural Heritage" Working Group of the International Photogrammetry Society (ISPRS). He teaches Architecture Metric Survey, and GIS and Modelling of Cultural Heritage at the Polytechnic of Turin and at the School of Specialization in Architectural Heritage and Landscape, Heritage Documentation at the Catholic University of Louvain (Belgium) and he is member of the Teaching's Committee of the International Research Doctorate "Technicians for Culture" at the University of Turin.

FROM PHYSICAL TO DIGITAL MODELS

Fulvio Rinaudo

The term "digital model" can be interpreted in different ways but the more general definition is a repository of (digital) data coming from different investigations able to give back a description of the investigated meaning of the object under one or more point of views and interest.
When we refer to the digital model of a 3D object, the first attempt to generate it is to provide a 3D metric model of the object itself, able to constitute the geometric reference frame to collect and correctly locate the other data to build up a georeferenced database of information.
The metric survey of an object, independently from its dimensions and shapes, is done today by generating a dense point cloud. Starting from these point clouds the segmentation and modelling phases have to be developed by considering both the required final metric quality of the 3D model and the structure of the final database.
The acquisition of the needed point clouds is today possible by using almost automatic systems based on the use of images (photogrammetry) or by using scanner systems based on direct distance measurements (Time of Flight) or on triangulation principle (e.g. structured light scanners, etc.).
The automatic tools usually available on the market (sometimes also free of charge) do not put too much attention on the obtained precisions and accuracies and the user is not driven to a serious analysis of the achieved results. The absence of the precision and accuracy information of the obtained results could drive the users of the survey towards improper uses of the 3D model.
In photogrammetry the precision strongly depends on the original pixel size of the used images, on the taken distances, and on the overlapping of the adjacent images. The theory says that if the taken axis of the adjacent images are parallel a precision of 10-4 of the taken distance (e.g. 0.1 mm for each meter of taking distance) is possible if the interior orientation parameters of the used camera and the optical distortions of the used lenses are generated by Laboratory calibration procedures.
Today the interior orientation parameters and the residual distortions of the optics are estimated during the photogrammetric process (photogrammetrically calibrated camera are no longer produced for terrestrial or drone image acquisition) and the needs of matching algorithms push the user to increase the overlap of adjacent images and to adopt convergent taken schemes. Therefore, the precision of the 3D point obtained by using photogrammetric techniques are not so easily predictable a priori. A precision and accuracy test of the obtained points is then required at the end of the photogrammetric process.
The 3D points acquired by using structured light-based scanner systems show precision that are certified by the constructors but each surveyed frame of points have to be registered on the adjacent ones. The precision of the 3D points acquired by using ToF scanner systems depends not only on the precision of the distance measurement but also on the precision of the angular movements of the measuring direction. In both cases the real precision and

accuracy of the generated point clouds must be tested at the end of the acquisition and registration steps.
It can be assumed that the measurement precision is generally greater than the precision of the obtained 3D points, and the precision of the final point clouds is usually lower than the precision of the single points due to the registration of the different acquisitions (in case of scanner systems) or to the relative orientation of the images (in case of photogrammetric systems).
Furthermore automatism do not means that metric survey solutions can be used by unskilled operator: they requires a good knowledge of the used measurement principles to avoid weak measuring conditions; a final check of the obtained precisions and accuracies is always mandatory to obtain the correct information for a successive correct used of the acquired point clouds for the modelling phase.
The first approach to the modelling phase needs the knowledge of the needed "composition" of the final model. A 3D model is formed by a set of 3D geometric entities which must be correctly defined by considering the data that have to be integrated in the successive phases. Let us consider a column: if the information to be added to the 3D model of the column refer to the entire volume of the column itself the geometric entity to be generated is the solid of the column. If the information to be added refer partially to the whole column and partially to the external surface of the column (e.g. external deterioration of the material, mold, vegetation, etc.) two different geometric entities have to be generated: the volume of the column and the skin which cover the volume of the column with a not significant thickness (e.g. 0.1 mm).
The selection of the 3D geometric entities must be conducted by the surveyors with the specialists who have provided the information to be associated to the 3D model. It is therefore an interdisciplinary work that must be developed before the modelling phase.
Once the elementary 3D entities are defined, the surveyor analyses the point clouds and starts with the possible geometric segmentation of them. The term geometric segmentation means the classification of the 3D points in multiple homogeneous regions with the same geometric characteristics (e.g. defining a plane or a more general simple surface). Some modelling platforms allow a preliminary automatic segmentation of the point cloud by defining the geometric rules to be respected; otherwise the selections could be performed by the surveyor by visually analysing the object. Each region is verified by making the statistical analysis of the existing discrepancies between the generated simple surface and the region of the selected point cloud. The acceptance of the proposed simple surface is subject to the analysis of the distribution of residuals that must have a null mean and m.s.e. not higher than the tested precision of the point cloud. Once a simple surface is accepted, the points used to define it can be deleted allowing, in many cases, a big reduction of the data to be recorded.
The points which are not substituted by simple surfaces are usually modelled by using algorithms able to describe

them or by triangles (e.g. planes) of minimum surface (e.g. Delaunay algorithms) or by spline surfaces. In this case the sharp edges will be lost and 3D models will appear smooth: the level of smoothness decreases when the density of the used 3D point increases (this problem must be taken into consideration also during the selection of the point cloud acquisition techniques).

After the segmentation steps, all the generated surfaces (simple and complex ones) are joined to define the 3D geometric entities: they are finally combined to form the 3D metric model.

The metric quality of the resulting 3D metric model, after all the transformations due to the segmentation and modelling steps, must be checked by comparing the obtained 3D model with the initial point cloud.

Also, the modelling procedure must be performed by skilled operators able to develop in a correct way all the steps which allow the build-up of the needed geometric 3D model. The main attention must be put on the preservation or limitation of the degradation of the precision of the 3D point cloud by considering its origin, therefore usually are the surveyors themselves who manage the segmentation and modelling phases.

The metric survey and consequent modelling procedures and strategies above described have been used for the 3D metric model production of the hand-made models of the Nubian Temples made by J.J. Rifaud available (thanks to the continuous and effective collaboration of the Egyptian Museum of Turin which is the owner of the surveyed models) during the duration of the project Back to The Future. As in each practical application of general theoretical concepts, the working procedures have been adapted to the real cases to give back not only the required 3D geometric models but also a certification of the metric quality of the achieved results.

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01 WOODEN MODELS, CASTS AND 3D PRINTS IN THE MUSEO EGIZIO: BETWEEN EDUCATIONAL AND SPECTACULAR APPROACHES

Alessia Fassone

Abstract

The production of models in the architectural environment dates back to ancient times, because of the need to show the structure of buildings and monuments not yet realized or not physically accessible. Nowadays, their use in the museums can have different purposes: study, education, scenic contextualisation, visualisation of images, graphics and data. Here we outline a brief history of 3D models at the Museo Egizio.

La produzione di modellini ha una storia antica, che nesce in ambiente architettonico dall'esigenza di mostrare la struttura di edifici e monumenti non ancora realizzati o non visitabili fisicamente. Attualmente, il loro utilizzo in ambito museale può avere diversi scopi: studio, didattica, ambientazione scenografica, visualizzazione di grafiche e di dati. Tracciamo qui una breve storia dei modelli 3D presso il Museo Egizio.

When, in 1821, the explorer Giovanni Battista Belzoni first set up a sensational exhibition on ancient Egypt in Piccadilly Circus[1], the audience had an enthusiastic reaction and hurried up to visit it in the so-called "Egyptian Hall" (now disappeared). Belzoni showed some life-size wall paintings of the Tomb of Sethy I in the Valley of the Kings, one of his most famous discoveries in Egypt, along with a 1:6 scale model of the tomb. Two other *maquettes* were displayed in the same occasion: the Pyramid of Khaefra at Giza (visible both in the outer and the inner part), and the temple of Ramses II at Abu Simbel. The visitors could also admire some real Egyptian antiquities, gathered in the fieldworks that Belzoni carried out along the Nile Valley.
Only three years later, in Turin, a collection of authentic objects coming from Egypt was bought by King Charles Felix from the French Consul Bernardino Drovetti[2]. Among these approximately 3000 pieces, some wood and wax models were included, depicting monuments of Egypt and Nubia, probably created by the artist Jean-Jacques Rifaud, one of Drovetti's agents on the Egyptian sites in the 1810s. Why they were accompanying the antiquities? The question is still pending, as far as we know, and some issues related to their production are to be cleared. A study is currently in progress and we do hope that it will shed new light on the purpose they were created for.
Undoubtedly, at that time few people had the opportunity to travel around the world, and thus only adventurers and traders could reach remoted lands, such as Egypt and Sudan. Scholars could try to imagine the monuments' appearance, based on book descriptions and illustrated plates only.

Despite the poor quality of the materials (wood and wax) and their fragility, the *maquettes* have been displayed both in the Museum's permanent galleries and in temporary exhibitions[3], to show the outer and inner structure of some temples in the Nubian area.

A quite different perspective pushed Giuseppe Ferlini to present to the Savoy kings a model of Queen Amanishaketo's pyramid and some copies of the jewels coming from her grave goods[4].

Ferlini was a military doctor who served in the Egyptian army during the occupation of Sudan in the 1820s. There, he explored many pyramid tombs in Merowe, hunting for treasures and antiquities. Because of the high fee he was asking for, only in 1840 he succeeded in selling part of the jewels to Bavaria and to Berlin Museum.

In 1994, the Museo Egizio hosted a small but precious

Fig. 1 - Model of the temple of Queen Nefertari at Abu Simbel, C. 7104. Photo by Giacomo Franco Lovera/Museo Egizio

Fig. 2 - Galvanoplastic copies of two jewels from the Treasure of Queen Amanishaketo, C. 6827bis/87 e 6827bis/83. Photo Museo Egizio

Fig. 3 - Cast of the false-door stela of Shery, head of the wab-priests of King Peribsen e head of the ka-priests of King Sened, C. 1476. The original is the Egyptian Museum Cairo CGC 1384, from Saqqara. Photo by Museo Egizio.

temporary exhibition, in which some of the original jewels and their copies were shown together[5].
Anyway, the spread of copies and models throughout Europe was crucial for the development of the Egyptological studies. The availability of several fac-similes of the Rosetta Stone and other hieroglyphic inscriptions allowed the French scholar Jean-François Champollion to crack the code for reading the ancient hieroglyphs.
This is the same spirit that animated the director of the Egyptian Museum in Cairo, Gaston Maspero, who sent to Turin in 1900-01 a series of 1:1 scale casts of significant relieves, mostly from the Old Kingdom tombs. This way, the Italian Egyptologists could improve their knowledge on some relevant monuments, just discovered.
Documenting the excavations and preserving the monument was the goal of the gorgeous 1:10 wooden model of the tomb of Nefertari, explored by Ernesto Schiaparelli in 1904. The painter Mariano Bartocci, collaborator of Evaristo Breccia in the Graeco-Roman Museum in Alexandria, was charged of reproducing the rich decoration of the Queen's burial. His copies were used for completing the maquette, built by father Michele Pizzio and Edoardo Baglioni[6].
The replicas accuracy allowed the restorers who worked on the wall painting in the late 1980s to imitate the original figures and colours[7], and in 2015 they were used for shooting a virtual tour of the tomb.
In the 1970s and 1980s, the educational efficacy of this type of reproduction caused a huge production of models,

Fig. 4 - Wooden model of the Tomb of Queen Nefertari in the Valley of the Queens, P. 3749. Photo by Giacomo Franco Lovera/Museo Egizio

Fig. 5 - Model of the tombs of Arinefer (TT290) and of Nakhtmin (TT291) ta Deir el-Medina, P. 3750.
Photo by Giacomo Franco Lovera/Museo Egizio

which were showing the structure of tombs and houses in Deir el-Medina, the pillared tomb of Iti and Neferu, the Step Pyramid of Saqqara and many other archaeological sites. Because of the lack of space, these objects have been progressively removed from the galleries and stocked in the storages. After the refurbishment, a new concept of model has been chosen: three videos show a virtual tour in the Tomb of Queen Nefertari, in the Chapel of painter Maia and in the just-discovered Tomb of Kha.

In the videos, made by the IBAM Institute-CNR, archival photos are processed and edited to create movement in the scenes and to convey the idea of three-dimensional spaces. The one illustrating the Tomb of Nefertari is completely built with shootings from the historical wooden model.

Very recently, the museum enhanced the use of 3D reconstructions for the exhibition "Invisible Archaeology", retracing the evolution of the techniques, from stereoscopic

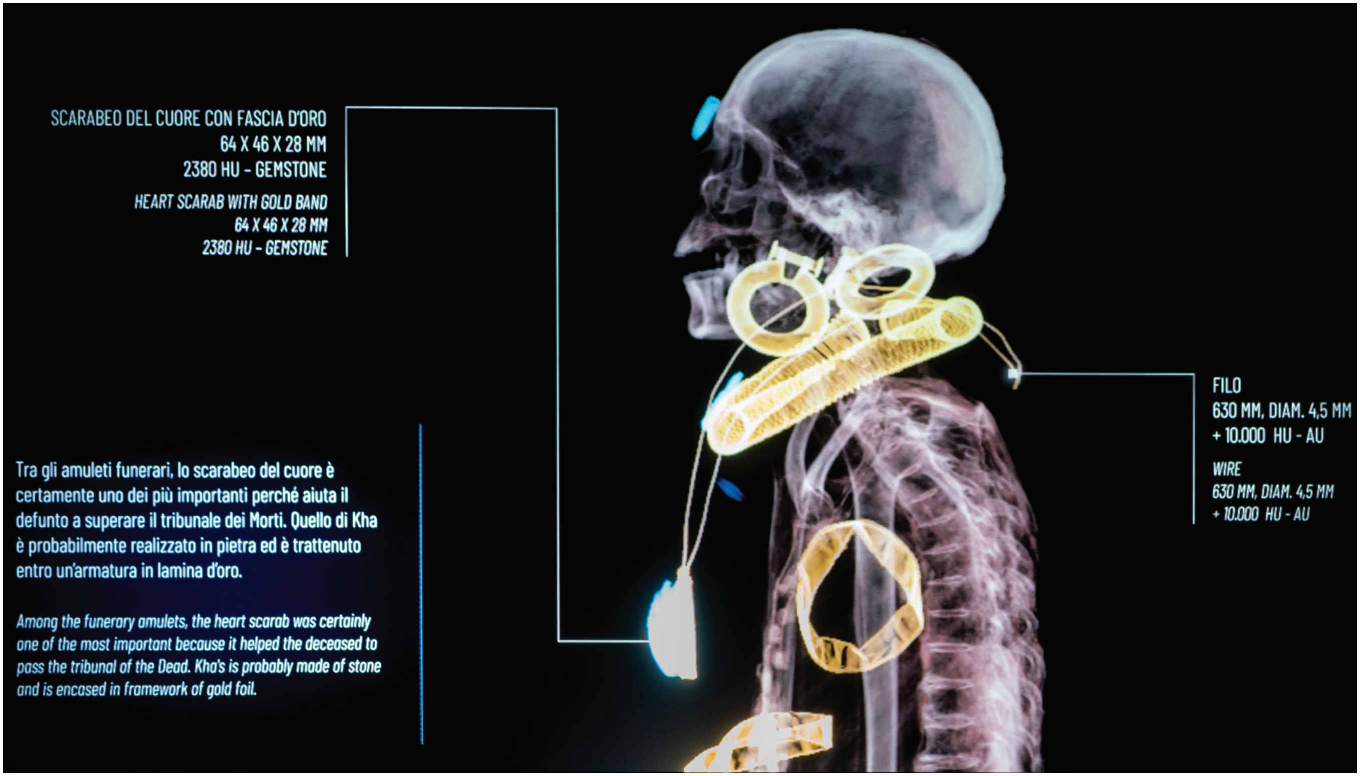

Fig. 6 - Exhibition “Invisible Archaeology” - documenting of the excavations: from stereoscopy to photogrammetry and 3d modelling. Photo by Nicola Dell’Aquila/Museo Egizio

Fig. 7 - Exhibition “Invisible Archaeology” - CT scan of Kha’s mummy, with his jewels marked gold yellow. Photo by Nicola Dell’Aquila/Museo Egizio

photography to videomapping[8].
With stereoscopy, two images shooted through a double-camera system suggest the idea of three-dimensionality, using a special viewer. In the Egyptian Museum’s archives over 100 stereoscopic plates are preserved.
In the last years, the fieldworks carried out in the site of Saqqara by the joint archaeological mission of the Museo Egizio and the Rijksmuseum van Oudheden of Leiden, are documented with photogrammetric images, processed with a 3D modelling.
The modern technologies allow us to view the invisible: the mummies of Kha and Merit still preserve the jewels on their bodies, hidden in the bandages. Nevertheless, through the CT scan technology is now possible to unwrap the mummies and to produce life-size 3D copies of their beautiful jewels. Previously, they were known only from the X-rays analysis, required in 1966 by Silvio Curto (former director of the Museo Egizio).

Fig. 8 - Exhibition “Invisible Archaeology” - Video projections on the 3D copy of the Royal Scribe Butehamon’s outer coffin. Photo by Nicola Dell’Aquila/Museo Egizio

Another evolution of such a technology is condensed in the perfect 3D print of the outer coffin of the royal scribe Butehamon. The video projections show the phases of its construction, from its carpentry to its decorative design. Thus, a digital replica can be also the visual support for information and conservation data.
In a future perspective, the digitalization process is to be intended as a tool of investigation and knowledge.

Notes

[1] Fassone, Giovannini Luca 2010, pp. 53 ff

[2] Einaudi 2016, pp. 501-506

[3] Curto 1976, fig. 54

[4] Donadoni, Roccati 1999, p. 170

[5] Priese 1994

[6] Moiso 2016, p. 79

[7] Corzo 1995

[8] Anonymous 2019

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02 DIGITALIZING DATA: FROM THE HISTORICAL RESEARCH TO DATA MODELLING FOR A (DIGITAL) COLLECTION DOCUMENTATION

Noemi Mafrici, Elisabetta Caterina Giovannini

Abstract

European cultural institutions hold an extraordinary tangible and intangible heritage not always accessible by the public for several reasons e.g. spaces, conservation, exhibition choices. Digitisation gives the opportunity to make heritage permanently available by scientists and by a wider public, placing replicas of artefacts of museums' collections in a virtual context.

This chapter is part of the B.A.C.K. TO. T.H.E. F.U.T.U.RE. project, coordinated by Massimiliano Lo Turco and presented in the preface of this volume. The research focuses on fifteen wooden architectural models of the early 19th century, part of the collection of the Museo Egizio of Turin. The maquettes are here denominated 'expedition models of Egyptian architectures', by referring to their original production. These artefacts suffered several movings, outside and inside the museum. The aim of the research is to connect virtual replicas of the models to narratives and the historical documents gathered during the historical research.

The chapter presents the collection as a whole, pointing out its historical and cultural value. With the aim to provide an exhaustive documentation and to create connections between artefacts and their documentation, the structure of the build database is here described. Starting from data and metadata available through the Museo Egizio database, a complex system has been created, following the CIDOC-CRM standars for the information modelling. A specific attention has been paid to the strategy developed for the 3D web-publishing, considering the presence of a centred information management system as fundamental.

Le istituzioni culturali europee posseggono un incredibile patrimonio tangibile, che spesso non può essere presentato al pubblico per motivi differenti, di spazio, di conservazione o per scelte espositive. La digitalizzazione dà la possibilità di riprodurre copie di artefatti che sono parte di collezioni museali, inserendole in un contesto virtuale, rendendole fruibili permanentemente non solo dagli studiosi ma anche da un pubblico più ampio.

Questo capitolo si inserisce all'interno del progetto di ricerca B.A.C.K. TO. T.H.E. F.U.T.U.RE., coordinato da Massimiliano Lo Turco e presentato nella prefazione di questo volume. L'oggetto della ricerca sono 15 modelli architettonici lignei di inizio Ottocento, parte della collezione del Museo Egizio di Torino. Con riferimento alla loro produzione, le *maquettes* sono qui denominate 'modellini di viaggio di architetture egizie'. Questi oggetti hanno subito moltissimi spostamenti, fuori e dentro il museo e l'intento della ricerca è quello di connettere le copie virtuali dei modelli a una serie di narrative e documenti storici raccolti durante la ricerca storica.

Il capitolo presenta la collezione nel suo complesso, sottolineandone il valore storico e culturale della serie completa. Con lo scopo di provvedere a una documentazione esaustiva e di creare connessioni fra gli oggetti museali e la loro documentazione, viene qui descritta la struttura del database costruito. Partendo dai dati e metadati disponibili attraverso il database del Museo Egizio, si è creato un sistema complesso, seguendo gli standard CIDOC-CRM per la modellazione di informazioni. Particolare attenzione è posta sulla strategia sviluppata per il 3d web-publishing, considerando come fondamentale la presenza di un sistema di gestione delle informazioni centralizzato.

Introduction

'Expedition models of Egyptian architecture' (EMEA) refer to a series of fifteen wooden architectural models, originally including fourteen models of temples or parts of the same, and one of an obelisk. The collection is conserved at the Museo Egizio of Turin but only a few items are displayed to the public. The rest of the models are stored in the depots of the museum or, in one case, currently undetectable[1]. Consequently, each model is as a single item with its distinctive catalogue number and the reference to the whole is barely perceivable.

At the beginning of the 19th century, expeditions in Egypt were a practice linked to the conscious discovery of the 'far away' to bring closer[2], and people going there wanted to record all the aspects and features their eye could frame. In the 1810s, the sculptor Jean Jacques Rifaud[3] joined the expedition of Bernardino Drovetti through Nubia and Egypt aiming to bring to Europe not only a valuable collection of memorabilia but also an unknown knowledge of architecture, botanic, folklore and features of the Egyptian population still not familiar to Europeans at that time[4]. Their journey took place within the European expeditions whose goods collected constituted the most important European museum collections of Egyptian objects[5].

The collection of the Museo Egizio of Turin has been largely formed by the 'Drovetti Museum'. The goods taken by Drovetti have often been literally reported with the word 'museum', first by William Turner in 1815[6]. The models were comprehended within Drovetti's collection that was transferred from Alexandria to Turin via Livorno and Genoa and considered for this reason already a museum collection of items. Even if nowadays the most part of the series is conserved in the museum's depots, as a part of the collection it continues travelling over the world, but the last moving of the whole series was more than fifty years ago[7].

The peculiar craftsmanship of the models is evidence of a practice that finds a rare example in the models. The wooden models, covered by plaster and painted, were assembled with different kinds of waste wood, and fixed with wax or nailed down, and they suffered different restorations in recent years. The conservation of the models has been taken lightly also during the first years at the museum, considering that they were among the few – probably the only ones - not original items produced by the Egyptian culture, but manufactured through a European expedition. Window cases for the models' preservation were only considered later[8]. These objects are evidences of an attempt to represent something new not only with drawings, sketches or more accurate iconography but they were also intended as a mean to reproduce an image, at that time still unknown in Europe. That image was vehiculated by the models, even more associating them with the other representations deriving from the same expedition. If each model gives the chance so that people could have an idea of the architecture and proportions of the monuments, their main value lies in the collection itself, particularly considering the poor accuracy of the same objects. A significant aspect is that the series represents something that is materially far from the museum and it provides an added value considering that several of the architectures are no longer existing there, flooded by the river or replaced out of the local environment.

Collection of data from a museum collection

The actual conditions and displacements of the models in different areas with different destinations of the museum reflect more an issue related to the complex itself: the series has not always been managed as a collection.

Considered as part of the 'Drovetti Museum' from the beginning (in Egypt), the model arrived with the rest of the collection of Drovetti to Livorno in 1818, as recorded into a report made by Vivoli[9]. The models remained there, in a bad state of conservation, until the end of 1823[10]. In Livorno, they were already treated as something standing-

by themselves, to the point that, in a first moment, they were not included in the transportation to the Museo Egizio with the rest of the Egyptian antiquities. The integration of 1823, that was made to the inventory of goods purchased from Drovetti's collection, included fifteen boxes containing architectural models of Egyptian monuments[11]: that was the first reference to the maquettes made within an official document. During the first part of the 19th century, the models were recognised as a distinctive set within the museum collection, as could be seen from the inventories, the guide and the set-up of the museum exhibition: indeed, all the models were exhibited in a room of the museum with a specific layout. Within the Orcurti catalogue of 1852, the architectural models had a specific section and a specific order: the models, numbered from 39 to 53, were included in paragraph 5 of the section 'Different monuments'. Although from the cataloguing of Rossi, Fabretti, Lanzone of 1888[12] they had no more a dedicated section and they were joined with the rest of the collection, losing their special catalogue numeration. Nevertheless, the models of monuments still remained all exhibited in the 'room 2' at the ground floor, and the collection remained unaltered in its position on display along all the century.
With the turn of the century, some additions were made to the museum collection with a huge number of objects deriving from new explorations. For this reason, a new inventory was necessary and also the exhibition had to change. The models were divided basing on the monuments they represented, separating the temples from the obelisk. The collection of models, still quantitatively composed of fifteen items, lost its place on display, and after 1967 one of the model, the item numbered 7114 in the catalogue, is no quoted anymore.
The consequence is that the entire collection is currently hardly recognisable as a whole and the value as an original series is lost. The historical research revealed these gaps and, within its objectives, the project has the double aim to make visible and usable what nowadays is hidden and to digitally recomposing the complete collection. With these goals, different kinds of data have been collected: guides, catalogues, inventories, correspondence of museum directors, exhibitions' plans and exhibits' catalogues.

source/content	*text*	*image*	*3d*	*nr.*
lithography	V	V		20
drawing	V	V		63
manuscript	V			4
object				14
3d model			V	26

Tab. 1 - Type of information that can be extrapolated by different kind of historical or archival source

A multidisciplinary approach

Today, the increasingly widespread use of the Internet and the new technologies applied to cultural heritage allow a very immediate type of dissemination in which the narrative plays a fundamental role in the creation of content, which should have both entertainment value, but also informative character.
The project aims to make the EMEA collection accessible online through the creation of a web portal in which the digital replicas of the models and the graphic and documentary apparatus collected, are presented simultaneously. Then, together with the historical researcher, a re-thinking and organizing of the data collected was done.
The research was carried on by different teams simultaneously: a first phase was covered by the elaboration of the digital models, carried out using photogrammetry technology. At the same time, the collection and the analysis of documentation available were made by the historian and the database manager that started to digitised a different kind of sources. Curating digital asset for EMEA collection was a work that saw the succession of many phases in which new metadata were created according to the development of the historical and archival

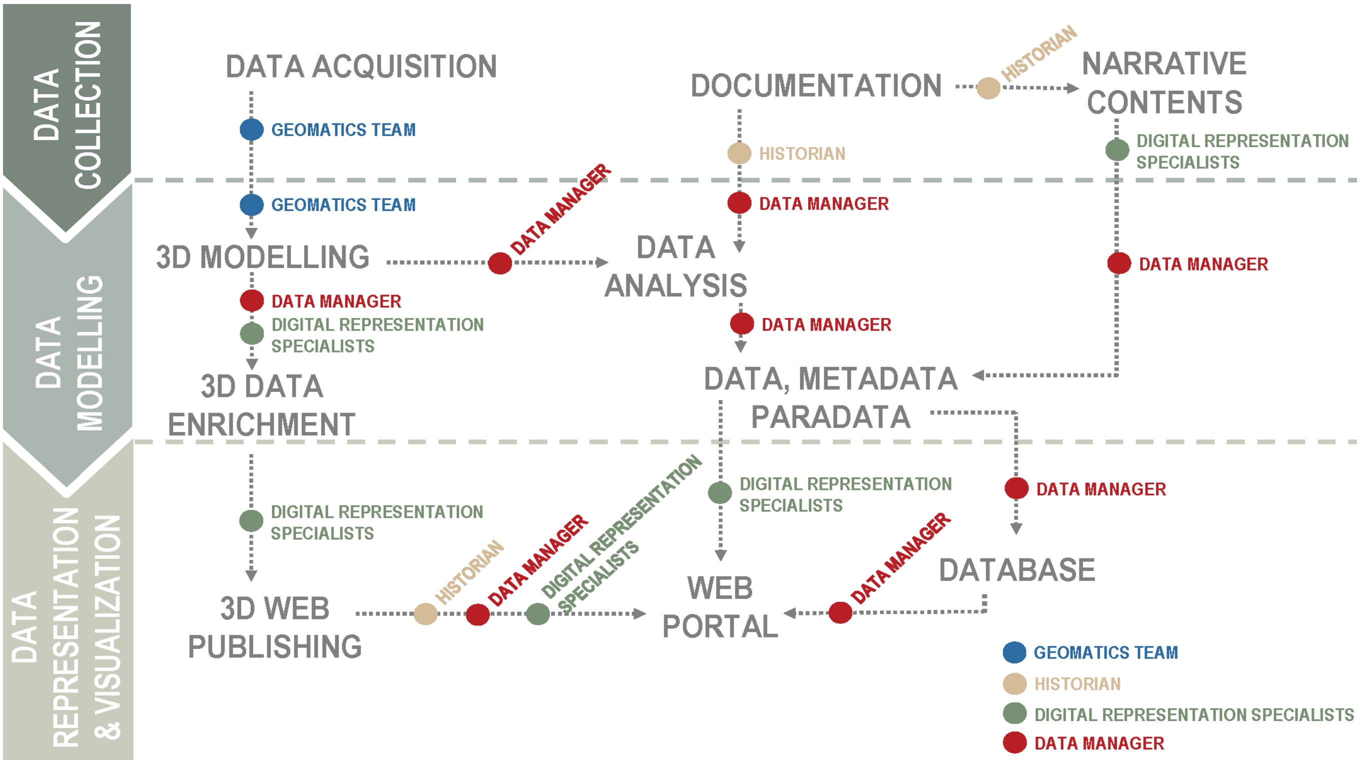


Fig. 1 - Phases of the research project and actors involved

investigation.
Designing and building digital project nowadays concern different activities, such as digitisation, classification, description and metadata organization and navigation.[13] All these activities involved different people with a different background: the curation of the content of the digital asset was made by the historian and the digitization phase and metadata curation of all sources was made by the database manager, taking into account the narratives purposes of the project and their on-line digital publication.
As previously mentioned, Jean Jacques Rifaud was a sculptor specialised in modelling wooden items and he was also one of the first explorers that publish a volume describing Egypt and Nubia. From the narrative point of view it was immediately clear that the maquettes should be associated with the contemporary representations of the temples that they depict. For this reason, the volume 'Voyage en Egypte, en Nubie, et lieux circonvoisins, depuis 1805 jusqu'en 1827' was chosen as the reference documentation. The Voyage should be composed of 8 volumes, 3 volumes composed by 300 planches, 100 per volume and other 5 volumes: 1) natural history, 2) Physics, 3) Archaeology, 4) and 5) planches' descriptions.[14] According to the maquettes available, considering the

selection of planches that describe the temple depicted, the digitisation of graphical and textual content was made (lithographs). This phase faces the challenge of digitising not only the standard metadata for archival management but also the intrinsic content of planches that must be converted in new metadata fields.
The creation of a product suitable both for documenting the research project both to enrich the ME database with new information should, in the end, also follow a standard available and recognizable in museum environment. Then to manage the different data collected within the project the CIDOC-CRM and its extensions were used to manage and organize data: according to the necessity to explicit data provenance[15] and paradata[16] information. The methodology applied to the project was divided into different steps that cover all phases involved in the digitization process for communication purposes of 3d contents:
- Data Collection (geomatics, historician and db manager)
    - Data Acquisition
    - Documentation
- Data Modeling (geomatics and db manager)
    - 3D modeling
    - data, metadata and paradata modeling
- Data Representation and Visualisation (db manager, historician and visual programmer)
    - Data base
    - web portal

DB Collection status and integration

The 'Expedition models of Egyptian Architecture' is a collection characterized by a homogeneous set of data stored in a central information management system: the database of Museo Egizio (ME database). Data and metadata in the ME database could be considered homogeneous because the collection has been little studied over the years, justifying the presence of only few records

ME Field	***New Field***	***CRM CLass***
ID Ogg	id_ME	E42 Identifier
User	user	E21 Person
User_last	user_last_modifier date_modifier	E21 Person E52 Time-Span
Collezione	current_location	E53 Place
Oggetto	object_appellation_1	E41 Appellation
Titolo/Descrizione	description	E62 String
N. d'inventario	n_inv inv_start_date inv_end_date	E42 Identifier E52 Time-Span E52 Time-Span
Categoria	category	E55 Type
Epoca	period	E4 Period
Materiale/tecnica	material type_material	E57 Material E55 Type
Dimensioni	x_part y_part z_part unit	E60 Number E60 Number E60 Number E58 Measurement Unit
Provenienza	provenance_location	E53 Place
Datazione	date_min date_max	E61 Time Primitive E61 Time Primitive
Collocazione	sub_location_00	E53 Place

Tab. 2 - Mapping records of the database of Museo Egizio (ME) of Turin using standard ISO 21127:2006 also known as CIDOC-CRM

to document the objects. The main challenge was to define a procedure to complete and integrate all missing and new information about objects and the archival ongoing research assuring the accuracy of historical contents and scientific knowledge production.
Starting from data available, the challenge was to create a system that could be as articulate and complete as possible, following the CIDOC-CRM standard to model information. The CIDOC Conceptual Reference Model (CRM) provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation.[17] Use a standard for conceptual modelling of data and metadata allows to describe different sources of cultural heritage environment

object	n. inv	name temple	name object	name file	web-page
	7101	Dakka	Model of the Temple of Dakka (Propylaea)	01_f	/propylaea.html
	7102	Abu Oda	Model of the Temple of Abu Oda	02_l 02_r	/abu-oda.html
	7103	Beit el-Wali	Model of the Temple of Beit el-Wali	03_l 03_r	/beit-el-wali.html
	7104	Small Abu Simbel	Model of the Small Temple of Abu Simbel	04_l 04_r	/abu-simbel.html
	7105	Debod	Model of the Temple of Debod	05_l 05_r	/debod.html
	7106	Gherf Hussein	Model of the Temple of Gherf Hussein	06_l 06_r	/gherf-hussein.html
	7107	Tafa South	Model of the Temple of Tafa South	07_l 07_r	/tafa-south.html
	7108	Dendur	Model of the Temple of Dendur	08_l 08_r	/dendur.html
			Model of the Temple of Dendur (Portal)	08_f	/portal.html

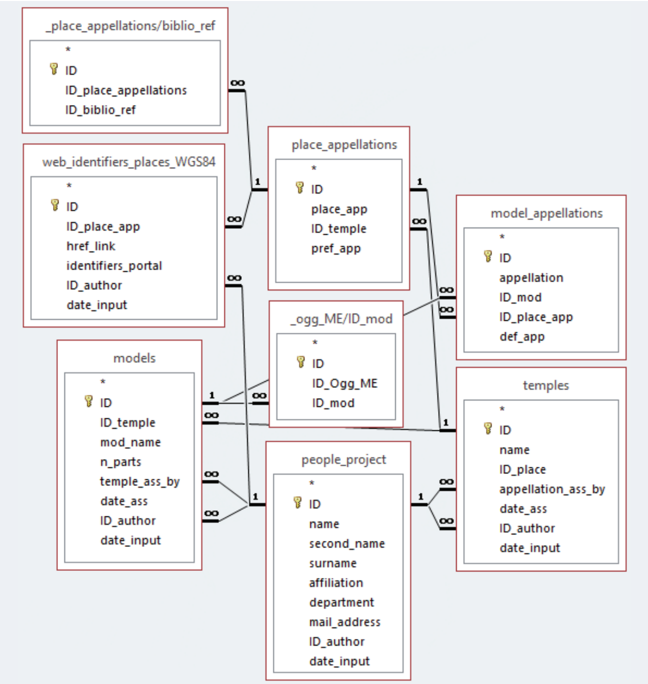
	7109	Dakka	Model of the Temple of Dakka	01_l 01_f	/dakka.html
	7110	Tafa North	Model of the Temple of Tafa North	09_l 09_r	/tafa-north.html
	7111	Debod	Model of the Temple of Debod (Portals)	05_f	/portals.html
	7112	Derr	Model of the Temple of Derr	10_l 10_r	/derr.html
	7113	El-Hilla	Model of the Temple of El-Hilla	11_l 11_r	/el-hilla.html
< MISSING >	7114	Maharraqa	Model of the Temple of Maharraqa		
	7115	Heliopolis	Model of the Obelisk of Heliopolis	13_o	/obelisk.html

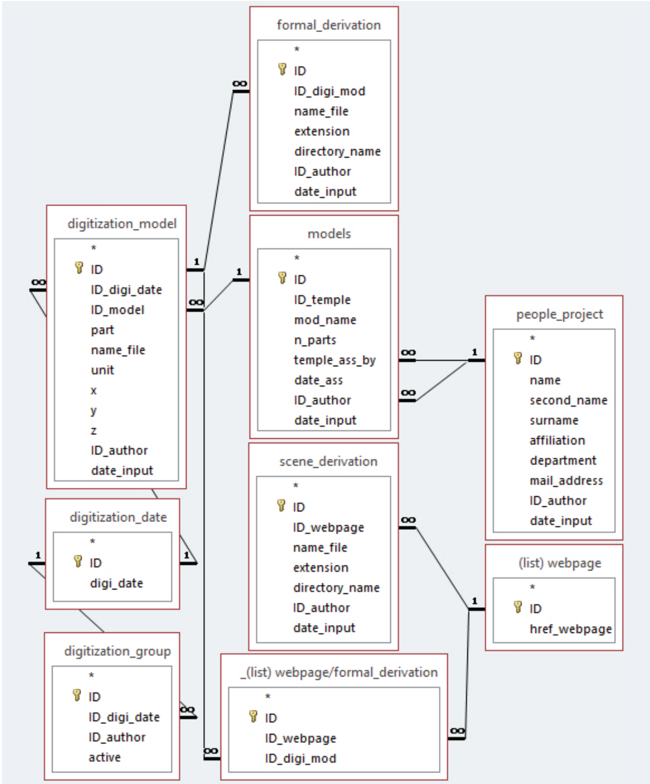
Tab. 3 - The 'Expedition models of Egyptian Architecture' Collection with encoding of the file name for the digitized models used in 3d scenes available on web-pages

using the same language.
In practical term, the procedure has the aim to move forward some targets of digital documentation:
integrating existing data without modifying the database of Museo Egizio
establish a conceptual data model to carry out the creation of new records suitable for documenting the historical research, taking into account the link between different kind of sources[18]
documenting the digitization process related to artefacts[19].
Digitised documentation of 'Expedition models of Egyptian Architecture' collection (EMEA) was stored in a specific information management system: a relational database system (RDBS). The choice of the software platform was driven by the necessity to have a direct link with the ME database that was developed using the same platform.
The front-end solution used by the Museo Egizio is a commercial web-based solution for museum management and it works as a mask directly linked to the original and very old ME database. The platform is designed to manage the entire collection, with thematic sections that permit the creation of a customized set of new metadata stored in a separate system. The solution, from one hand solve the migration problem of the entire original database, but from the other hand, it allows to generate metadata in an uncontrolled way. Fortunately, the studied collection EMEA was poor of metadata and was re-designed using standard ISO 21127:2006.
In the user interface available, records stored in the database concern only general information. The main mask can be divided in different areas: on the top, on the right side, there is information related to the object ID (in the database) and the active user. Near the user identifier there are fields related to last change, with a specification about user and date. The top area has a frame to show images of the object.
Other general records are shown in the main top area.
Record 'collezione' identifies the reference collection, which addresses only the Egyptian Museum as a possible selection option. Objects are often titled and described using the same nomenclature, sometimes with a redundant value. The preferred inventory number follows the cataloguing of 1888.
In the lower part of the mask, there is a tabbed menu for multiple data-pages dedicated to various topics. In this case, for most of the objects in the collection the data available are able to fill only the 'Generic Data' tab.
Other records are 'Dimension' where the measurements of the object are indicated without single reference lengths. Moreover, following the analyses carried on the three-dimensional acquisitions of the objects, the measurements already present in the ME database were different.
In general terms, the 'location' is divided into 'Location' and 'Current Coll.' while it would be more appropriate to consider a single field for the indication of the location and in addition another field to indicate the time extension of permanence in single places.
With reference to the individual objects, each of them has associated records of belonging to the exposures in which they took part: 'exhibitions' and 'exhibitions_title'.
The most innovative part of the project lies in the use of a database to collect historical information and documentation relating to different types of sources. The possibility of creating direct links between the model and the existing documentation oriented to the web-publishing is part of the ongoing research.
The documentation collected concern both the historical research and the photogrammetric survey campaign carried out by the geomatics team. According to CIDOC-CRM classes, the available records for each object were re-assigned.
After the first phase of analysis and re-modelling of available data, the second phase was related to the metadata creation for the documentation of the digitization process. The main challenge was to create a new classification for information about the objects taking into account the

Fig. 2 - database relationship structure for the models appellation

Fig. 3 - database relationship structure for digitization data structure





morphological consistency of each one: most of them are composed by two parts, that must be referred to a unique ID Ogg in the ME database.
Since the historical and archival research has started, it was clear that each maquette represents a Temple or a part of it. Then a classification based on the Temple represented by maquettes was done. Finally a list of twelve temples and one obelisk was created for the assignment of fifteen objects. The 'temple' table contains an ID as primary key that is generated automatically by the system, then other records related to the person that made the assignment of a specific name to the Temple was defined, assuring the paradata traceability. In this case the 'persons' table collects a list of people that are working within the same project and their specific attributes. After the definition of the right correspondence between a Temple and the Object, another issue was related to the correct Appellation of the Temple. The historical research, in fact, shows how, depending on the source to which reference is made, the historical period and the geographical area of belonging of the various authors, the temple could take a different name: the choice, according to main documentation collected, was to follow a nomenclature based on the place to which the temple pertains.
The 'place_appellation' table store a list of available names and it links them to more specific tables for available data

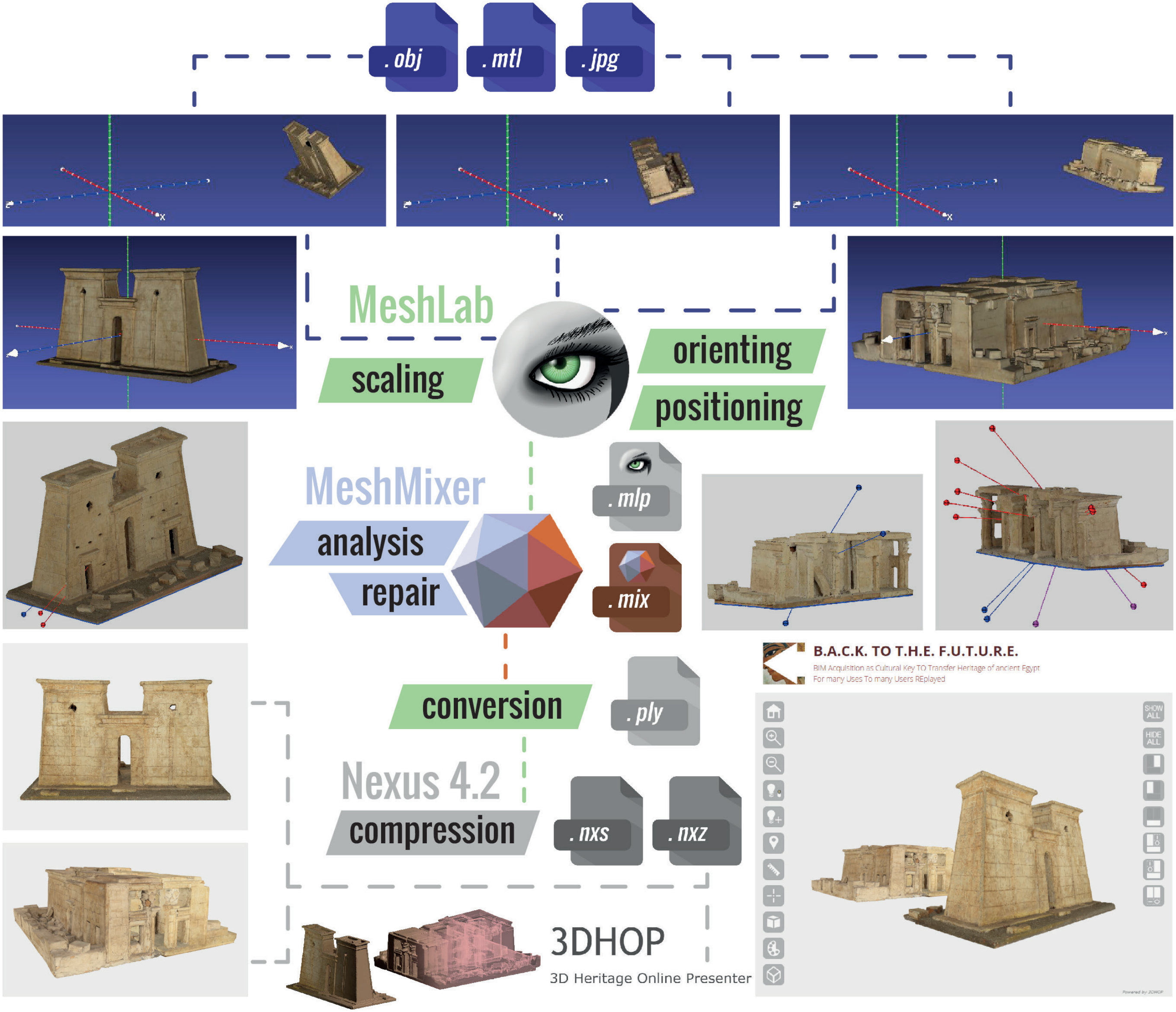


Fig. 4 - The workflow of 3D web-publishing using 3dHOP

Fig. 5 - Screenshot of the web interface for the visualisation of the *3D Model of the Temple of Dakka* and related documentary heritage

provenance: in this case, a list of URI collected within the web and a bibliographic list or references. In the 'models' table a set of records were defined to link the object to the temple that represents documenting the attribution phase both for the temple that for the name of the object.
A new name/title was assigned to the object in accordance with the temple name, even if a set of possible appellation for each object was stored in the 'model_appellation' table. According to the ID of the 'temple' table a new encoding to objects and their part was assigned. The same code was used for the naming of digitization files. From the other hand the use of the name of places was preferred for the naming of folders and web-pages.
According to the new encoding of the parts of the object a set of new tables was created to manage the digitization process. The 'digitization_model' table contains records related to the object acquired with photogrammetric technique. The table is also linked to information about people that attended the acquisition campaign: 'digitization_group' table. Because of the needs of the museum and the availability of maquettes, the acquisition campaign of the entire collection was made in different dates, listed in the 'digitization_date' table, so it is possible to check which models were acquired in different dates and who acquire them.
Thinking about the number of files generated for the 3d web publishing, the 'formal_derivation' table was created to store all single file for each acquired model's part and the derived file produced. To obtain the final 3d model to publish on the web according to the necessity of develop a single web-page for each object, different scenes were developed with both parts of each model, but also

following the historical narratives output of the project, we decided to create other three web-pages to visualise not only objects but also Temples and their complexity, creating scenes with a combination of at least two objects: data about the scenes files were stored in the 'scene_derivation' table.
Starting from the structure of the back-end, a pilot front-end was tested, using 3DHOP (3D Heritage Online Presenter) a software package for the creation of interactive Web presentations of high-resolution 3D models.[20]

Conclusions

The structure for EMEA database described, shows how could be possible manage different kind of sources available, starting from a digital acquisition and how to re-structure data from a database already designed. The aim, as mentioned before, was to provide as complete documentation as possible for each object of the collection and at the same time trace information and knowledge about the development of the 3d web-publishing phase. Tracing the relationships between objects and documents, not only using a web-page but also and above all through the use of a central information management system should be a recommendable practice. Systematize data and information for future studies and for the re-use of information is possible only with a declared structure of data, allowing future developments in historical research but also the re-use and re-thinking of narrative outputs.

Notes

[1] The models of the temples of Beit el-Wali, Tafa south and a part of the temple of Dakka are exhibited in the Temple of Ellesiya/Nubian room of the museum. The models of the small temple of Abu Simbel, Balagna, a part of Dakka with its propylaea, Debod with its portals, Dendur with its portal, Derr, El-Hilla, Gherf Hussein, Tafa North and the Obelisk of Heliopolis are stored in different part of the depots of the museum. The model of the temple of Maharraqa is currently undetectable. It has been registered as part of the collection from its arrival in Italy until the 1967, on the occasion of the temporary exhibit in Milan.

[2] See Thomas 2012.

[3] Jean Jacques Rifaud (Marseille 1786 - Genève 1852) was a sculptor by training, specialised in modelling wooden items. He joined the Drovetti expedition in 1814 and took part also in the excavations activity of Thebes, Fayoum, Karnak and Tanis.

[4] See Bruwier, Claes, Quertinmont 2014.

[5] The antiquities collected in Egypt by Bernardino Drovetti, Henry Salt, and Giovanni Belzoni led to the formation of the Egyptian collections of the Louvre, the British Museum and the Museo Egizio of Turin.

[6] See Ridley 1998, pp.250-251.

[7] *Incontro con una civiltà millenaria: mostra dedicata all'Egitto antico e contemporaneo*. Milano: Centro culturale Pirelli, 10-25 marzo 1967.

[8] Fourteen cases were bought in 1842 to cover the models of the temples and a glass domes to cover the obelisk has been inventoried only in 1868; 'quattordici case di vetro per sottrarre alla polvere ed al gr coprire I modelli dei templi della Nubia che fatti con legno e cera già soffrirono alquanto per mancanza di questo riparo 370 lire' ASTo, I vers., mazzo 3, fasc. 1; 'una campana in vetro e piedistallo in legno per un piccolo modello in cera di un obelisco egizio' ASTo, mazzo 1, fasc. 9.

[9] '[...] la raccolta è accuratamente descritta, si parla anche dei modelli in rilievo di legno incerato degli edifici egiziani che non potevano trasportarsi, e si dice che è frutto delle fatiche di sedici anni del console francese in Alessandria Signor Drovet (sic)', in Bresciani, Edda (2000). *La Piramide e la torre: due secoli di archeologia egiziana*. Pisa: Pacini, p.20.

[10] 'In secondo luogo per ciò che riguarda il miglior modo di spedire il rimanente della Collezione, composto ancora di numeri 307, tra statue, casse e colli, oltre le quindici casse di modelli che il Capitano Palazzo porterà forse da Livorno nel prossimo dicembre, ho l'onore di far presente all'Ecc. Vostra che fra quei monumenti ve ne saranno ancora dieci o dodici del peso di Rubbi di Genova 140 ai 160; ed altri dieci o dodici di R 60 ai 100.'San Quintino letter, November 30, 1823.

[11] 'Rimangono qui quindici casse contenenti modelli di antichi templi ed edifizi egiziani fatti di legno coperti di cera, non avendone trovata menzione nel catalogo io non ne ho domandata la remissione; ieri

il S.r Pedemonte mi disse che avrei potuti mandarli col rimanente, ma essendo le loro case tutte aperte, e mezze rovinate, non avrei più potuto rassettarle senza trattenere il bastimento, con suo danno in questa difficile stagione.' San Quintino letter n.2612, November 1, 1823.

[12] Lanzone, Ariodante, Rossi, Francesco, & Fabretti, Ridolfo Vittorio (1888). Regio Museo di Torino ordinato e descritto da A. Fabretti, F. Rossi e R.V. Lanzone. In Ministero della Pubblica Istruzione (edited by), *Catalogo Generale dei Musei di Antichità e degli Oggetti d'Arte raccolti nelle Gallerie e Biblioteche del Regno*. Roma: Direzione Generale delle Antichità e Belle Arti, pp.307-309.

[13] Cit. Burdick et al. 2012.

[14] Cf. Claes 2014.

[15] W3 (internet) http://www.w3.org/2005/Incubator/prov/wiki/What_Is_Provenance

[16] Cf. Denard 2012.

[17] CIDOC-CRM (internet) http://www.cidoc-crm.org/

[18] Cf. Lo Turco, Calvano, Giovannini 2019

[19] Ibid.

[20] 3DHOP (internet) http://3dhop.net/

Noemi Mafrici is author of paragraphs *Introduction* and *Collection of data from a museum collection*. Noemi Mafrici and Elisabetta C. Giovannini wrote the paragraph *A multidisciplinary approach*. Elisabetta C. Giovannini is author of paragraphs *DB Collection status and integration* and *Conclusions*.

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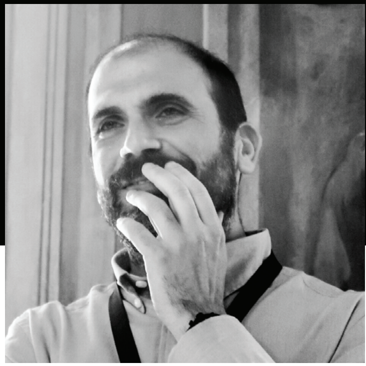

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Architect, PhD in Architectural Representation (SSD ICAR / 17). He carries out research activities on the digitization of museum environments at DAD (Politecnico di Torino). He teaches at the Camerino University in the 3D Modeling Lab in the Master’s Degree Course in Computational Design of the SAAD (Ascoli Piceno); he carries out further training activities in the representation courses of the Politecnico di Milano and IUAV in Venice. Coordinator and teacher of workshops focused on Digital Fabrication processes. The research activity is aimed at the study of responsive surfaces and new methods of “remote survey”. Lecturer at the AANT Academy of Arts and New Technologies (Rome) in the course of Digital Modeling and Rapid Prototyping. Co-founder of the ArFacade studio (www.arfacade.com) specialized in design and development of architectural envelopes.

03 DIGITAL MODELS OF ARCHITECTURAL MODELS : FROM THE ACQUISITION TO THE DISSEMINATION

ALESSANDRA SPREAFICO, GIACOMO PATRUCCO, MICHELE CALVANO

Abstract

Antiquities and works of art preserved in museum collections represent an invaluable evidence of our history. A proper three-dimensional metric survey and digitisation of these assets (which are intrinsically fragile and for this reason need a continue and careful documentation) allow to increase significantly their resilience and they offer a valid contribution for the management of these objects belonging to movable heritage.
This work takes place during a research experience carried out in the framework of B.A.C.K. TO T.H.E. F.U.T.U.RE. (BIM Acquisitions as Cultural Key TO Transfer Heritage of ancient Egypt For many Uses to many Users REplayed) during which a collection that consists of fourteen wooden models belonging to Museo Egizio of Torino has been digitised using both image-based and range-based modeling techniques. In addition to geometric and radiometric data, provided by textured model, information of various nature related to the considered asset has been integrated. The main aim of the research, starting from the digital 3D models, is the creation of three-dimensional databases (with alphanumeric and multimedia informations about historical, artistic and management aspects), useful for several purposes: 3D visualisation, communication, dissemination and data management. In this paper 3D metric acquisition strategies have been evaluated and the followed methodology as regards data enrichment have been illustrated.

I reperti e le opere d'arte conservati nei musei rappresentano una testimonianza insostituibile della nostra storia. Un adeguato rilievo metrico 3D e la digitalizzazione di questi beni (che sono intrinsecamente fragili e per questo motivo necessitano una continua e attenta documentazione) consentono di aumentare in maniera significativa la resilienza e offrire un valido contributo alla gestione dei beni appartenenti al patrimonio mobile.
Questo lavoro è stato svolto durante un'esperienza di ricerca condotta nell'ambito del progetto B.A.C.K. TO T.H.E. F.U.T.U.RE. (BIM Acquisitions as Cultural Key TO Transfer Heritage of ancient Egypt For many Uses to many Users REplayed) durante la quale una collezione composta da quattordici modelli di legno appartenente al Museo Egizio di Torino è stata digitalizzata con tecniche di modellazione image-based e range-based. Oltre ai dati geometrici e radiometrici, forniti dal modello texturizzato, sono state integrate informazioni storiche e gestionali relative ai beni considerati. L'obiettivo principale di questa ricerca, a partire dai modelli digitali 3D così ottenuti, è la creazione di database tridimensionali (contenenti informazioni alfanumeriche e multimediali a proposito di aspetti storici, artistici e gestionali), utili per molteplici scopi: visualizzazione 3D, comunicazione, diffusione e gestione dei dati. In questo articolo sono state valutate le diverse strategie di acquisizione metrica 3D ed è stata illustrata la metodologia seguita per quanto riguarda il data enrichment.

Objects preserved in museum collections have always been a valuable evidence of our history and our heritage. The need to document these priceless assets is undeniable and it requires a careful consideration about the techniques and the methods for the entire digitisation process[1]: from the physical object, through the digital model and its data enrichment to the divulgation step. These digital models are extremely versatile as regards not only research purposes: as 3D documentation to increase the resilience of these valuable and fragile assets, as basis for various analyses by experts operating in the framework of movable Cultural Heritage valorisation[2], but also as tool for online dissemination[3]. This experience takes place in the framework of B.A.C.K. TO T.H.E. F.U.T.U.RE. research project[4] and proposes a procedure for the digitization and data enrichment of museum collections; the path has been made up of a series of case studies: 14 'travel models of Egyptian architecture'. A collection that originally included thirteen temples and an obelisk now belonging to the Egyptian Museum in Turin. The survey and information enrichment are well-known operations on an architectural scale, but not for small objects, which is why the path taken by the research group was a starting point for investigation in different fields. Procedures and tools suitable for describing the shape have been identified; at the same time, historical and artistic information has been collected for subsequent information enrichment. The data collection phase was followed by the merging of shape and information, work carried out with the operation of final dissemination in mind; a series of models linked to databases useful for the digital documentation of the objects detected.

Geomatics methods and instruments for museum collection

In the last few years, increasingly users operating in the fieldworks of 3D modelling have investigated the strategies for movable heritage digitisation in order to define the most efficient acquisition methods considering not only the geometric information, but also data about the radiometry and the consistency of the considered assets[5].
In this regard, the role of the Geomatics has been decisive. Since the development of new sensors, range-based techniques, image-based techniques and, connected to that the improvement of photogrammetric computer vision technologies and image-matching algorithms, the Geomatics has provided effective tools as regards movable heritage 3D metric acquisition and the realisation of very detailed 3D models[6]. Generally, for the digitalisation of these kinds of objects (such as those acquired during this research), different methodologies are usually adopted, the image- and the range-based approaches and the structured light system exploiting the triangulation principle[7]. The present case study considered different scanner instruments and digital images processed using Structure-from-Motion (SfM) algorithms following metric criteria.

Acquisition and Modeling of the wooden maquettes

During the research activities illustrated in this paper, the acquisitions of the 26 pieces (smallest one 23x23x65 cm3, biggest one 42x106x41 cm3) (Figure 1) composing the 14 maquettes of the Nubian monuments (2016), have been carried out in six surveys between February 2018 and April 2019 and testing the suitability of the following sensors (Figure 2):
Laser-based and structured light-based active sensors:
(1) Terrestrial laser scanning system Faro Focus 3D
(2) Hand-held structured light scanner Faro Freestyle
(3) Hand-held structured light scanner Stonex F6 SR (Short Range)
Image-based passive sensors:
(4) High-resolution full frame digital camera Canon EOS 5DSR equipped with a Zeiss 50 mm macro lens.

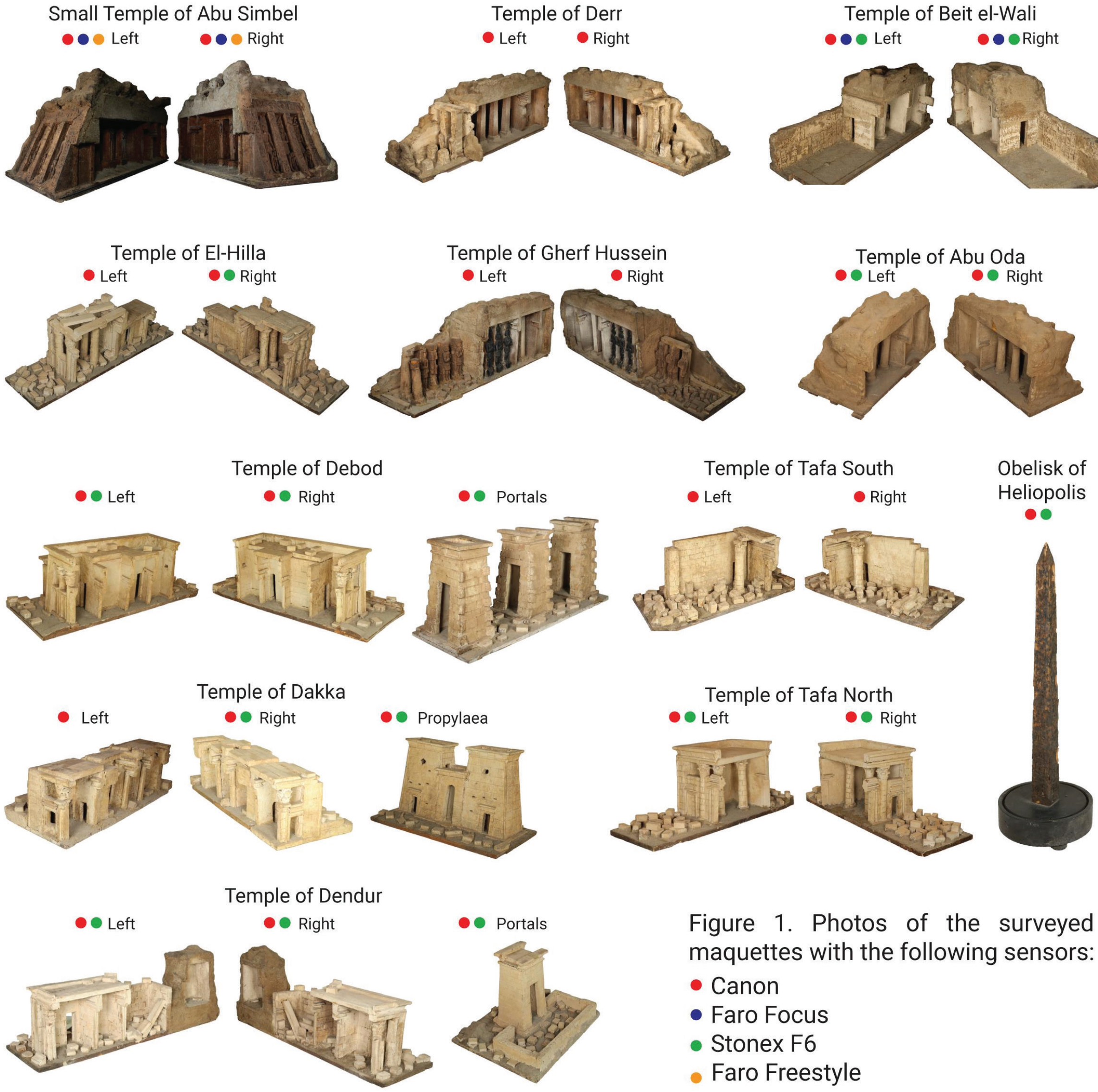

Figure 1. Photos of the surveyed maquettes with the following sensors:

- Canon
- Faro Focus
- Stonex F6
- Faro Freestyle

Fig. 2 - From right to left: (1) Faro Focus 3D 330, (2) Faro Freestyle, (3) Stonex F6 SR, (4) Canon EOS 5DSR with Zeiss Milvus 50 mm f/2M lens

The geometric accuracy is evaluated thanks to metric bars positioned in the acquisition stage.
As regards the processing phase, according to the type of acquired data and to their level of completeness, different approaches have been considered: image based, range based and integrated solution merging different datasets. The latter has been already presented in Lo Turco et al 2018.
Basically, the point cloud obtained by the data processing of the acquired datasets, both for range and image based sensors, represents the starting point as regards the metric survey and the 3D modelling; from the proper interpretation of the point cloud - or the union of different point clouds - a Triangulated Irregular Network (TIN) of each maquette has been generated following five steps (Figure 3):
1. Editing of the point clouds (e. g. removal of outliers, filter for noise reduction, etc.).
2. Manual segmentation of the point clouds in order to identify the regular surfaces (e. g. the walls of the temples) which can be approximated to a flat geometry with small discrepancies (less than 2 mm). For each segment a discrepancy analysis has been performed in order to evaluate the acceptability of the simplification.
3. Interpolation of the flat surfaces through least square interpolation and topological reconstruction. During this phase a simplified mesh has been triangulated from each of the flat surfaces.
4. Creation of the final mesh, obtained from the union between the flat surfaces and the reality based high-resolution TIN generated from the acquired point clouds.
5. Texturization of the 3D model, exploiting the same coordinate system of the same model for different datasets.
The aim of these workflow is to obtain an optimized 3d model for data enrichment and digital visualisation, therefore weight, geometrical and radiometric completeness of the model are key factors.

Best strategies for reality-based modelling

For the purposes of this research, beside the metric accuracy of the obtained models, three other principal aspects have been considered: rapidity, level of detail and model texture; in particular, the presence of a texture allows to provide valuable information about consistency of the materials that compose the maquettes.
The sensors more suitable for this type of digitisation have proved to be Canon EOS 5DSR (as regards the image-based approach) and Stonex Smart F6 (as regards active

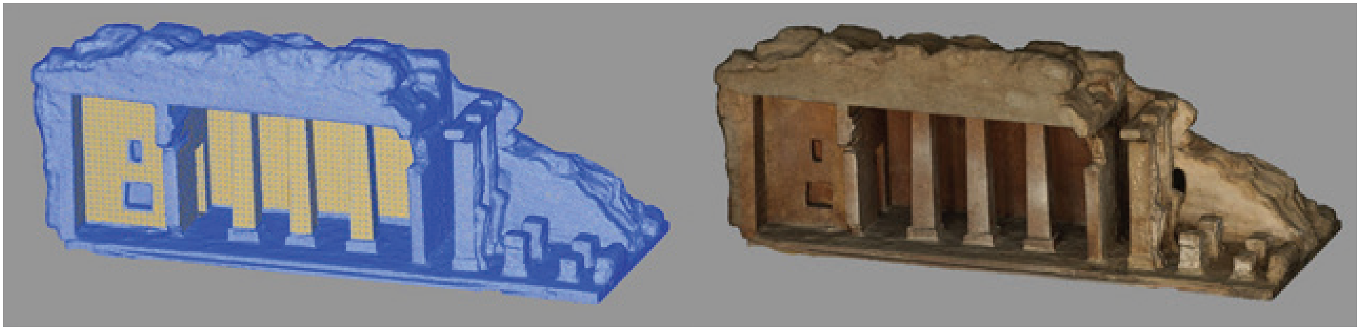

Fig. 3 - Example of final 3D model (with and without texture

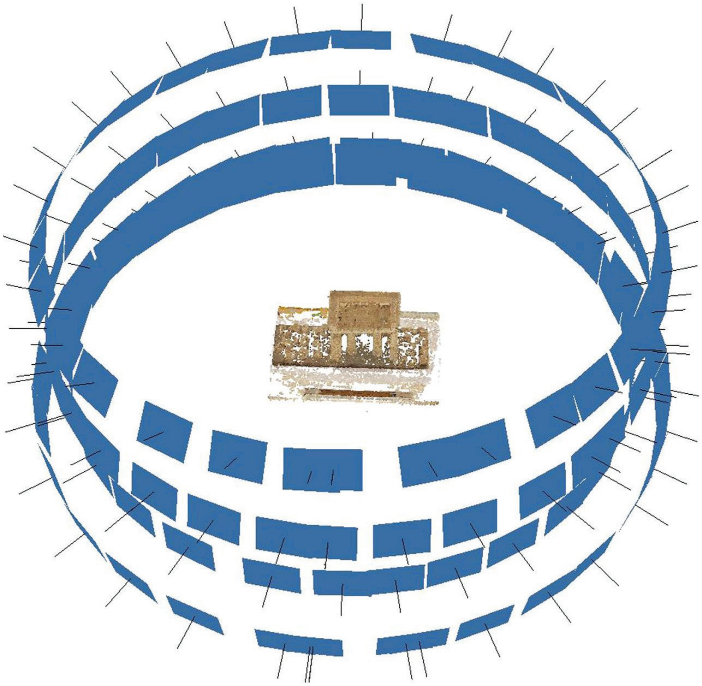

Fig.4 - Strategy of acquisition through circles with four different assets (left): in blue images alignment and in the middle the SfM based tie-points extraction. Positioning of the maquette and photogrammetric set (right)

sensors), in terms of level of metric accuracy, reached level of detail, quality of the texture and time-spending from acquisition phase to the creation of the final model.
The photogrammetric strategy has been proved as extremely competitive, not only as regards the texture, the level of detail and the millimetre-level accuracy, but also as concerns the rapidity of the acquisition. In fact, a rotating platform enabled to rotate the wooden maquettes in order to record multiple images from different points of view; this strategy optimized the focus control of the image and the movements of the photographic tripod, with a considerable reduction of the acquisition time (for each model about 100-150 images have been acquired in about 20-30 minutes). The acquisition of the images has been planned with four different camera assets in order to cover most of the surfaces of the maquette, even those hardest to reach because of complex morphology of these objects such as the parts covered by the colonnade or other obstruction (Figure 4). Nonetheless, the fixed point of view of the camera with the same background and changing position of the model negatively affect the relative orientation during the photogrammetric elaboration based on SfM algorithm. In order to overcome these problems, during the data processing phase masks (Figure 5) have been applied to the acquired images in order to perform the tie points extraction only in the areas of the images representing the acquired object.
As regard the Stonex F6 SR, rapidity and free movement typical of handheld solution are competitive factors, but ability to work without markers, colour recording, real time visualisation and short-range working distance increase its affordability in case of movable cultural heritage. In fact, the F6 SR is a structured light system able to capture 640000 points per second within a range of 25-50 cm with declared sub-millimetric accuracy. In the tested field, the coloured point cloud of a single maquette has been acquired in about 5-15 minutes, speeding up both the acquisition and processing phases. In fact, an integrated RGB camera permits to associate the material colour of the object to the point cloud captured with a triangulation infrared light-based principle (Figure 6). Nonetheless its metric accuracy and colour reproduction of the texture are still under analysis because influenced by operator behaviour, object material and lighting conditions.

Design and implementation of a prototype procedure for information modelling

One of the aims of the research is the online publication of the surveyed models; this operation is possible using

Fig. 5 - Masking of the images: (left) image as acquired, (right) image with mask on the background

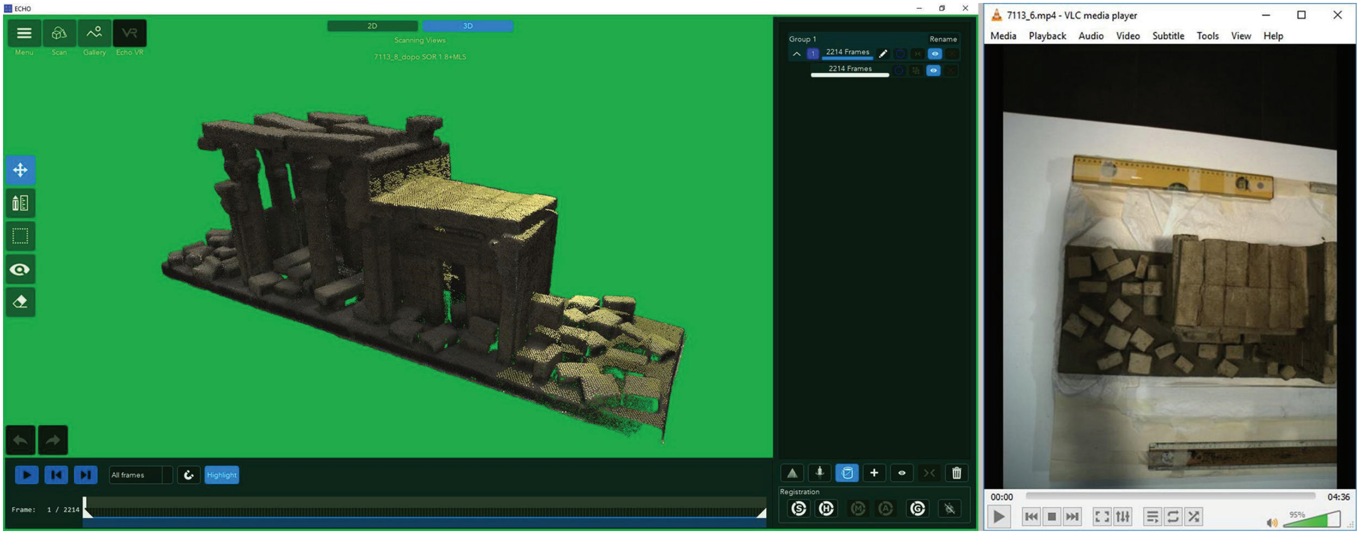

Fig. 6 - Right maquette of the temple of El-Hilla acquired by Stonex F6: Point cloud (left) visualised in the Echo software where the portion highlighted in yellow correspond to the frame captured at the same time with the RGB camera (right)

applications for the interactive navigation of high-resolution digital models. In addition to the visualisation, there is the aspect of dissemination of historical and managerial information. The model can be viewed and dynamically selected in some parts within a standard Web page; hotspots guarantee access to alphanumeric and multimedia information derived from historical, artistic and management surveys.
We start from the numerical model (mesh) that generally represents the object by means of a single polyhedral surface that morphologically, does not clearly express the parts that make up the acquired objects, except through the information coming from the texture projected on the model.
It was therefore decided to introduce an annotative phase to define parts of shapes (semantic recognition) and functions that make up the entire model. The models examined are small-scale reproductions of architecture, so the recognition of architectural parts is important for the understanding of the architecture maquette.
Data modeling for dissemination involves operations for the implementation of historical and artistic information relating to the entire maquette or some of its parts, an operation that in our research took place in a CAD environment and on two-dimensional images. The annotations foreseen are of different types:
a) general annotations - involve the entire model and provide a general description of the object (year of construction, author, historical and artistic context, etc.);
b) circumscribed notes - recognize parts of the object by providing functional information of the model, sculptural elements, etc.;
c) dot annotations - useful when shading and texture delimit parts of the model visually, so punctual reference can easily be associated with an area of the model.
The enriched model is then displayed and queried in a web

environment. The interoperability between CAD and Web environment is solved by means of a visual programming language (Grasshopper), an open tool for research that can be easily implemented even by non-informaticians.
We can mention in the annotative procedure for the Collection Information Modeling (CIM) different phases that are distinguished by the actions carried out and the relationship with space[8]. The workflow can be summarized in the following points:
1. creating images from the model;
2. notes on images;
3. remapping 2D annotations in 3D;
4. implementation of the 3DHOP html code for the reiterative parts.

Generating images from the model

The annotative phase, being addressed to experts in different fields of knowledge, takes place in a simplified digital environment (on the XY system of the CAD environment), easily editable, so on two-dimensional images of the model. The images used are the result of the 3D model's projection on the faces of its bounding box (fig. 8). For complex models, characterized by internal spaces, the automated procedure is able to produce section images (Figure 9).

Annotations on images

The images are then reopened in 2D space by a drawing software with which to trace points and areas of different complexity that can be represented with common digital drawing tools, but equipped with tools for enriching data of simple geometries. In figure 10, the annotation operation is illustrated on a front view of the minor temple of Abu Simbel on which to identify an information hierarchy in relation to the methods of annotation. When the image is selected, an annotation window opens in which you can provide information on the characteristics of the model: attribution, historical period of construction, materials, the object's journey through time, etc. For the semantic annotation, a closed polyline is introduced, even if irregular, in order to frame the portions of the image to which the data reported in the appropriate windows refer (Figure 10). The annotation strings can also be compiled with links to multimedia content and images.

Remapping 2D annotations onto 3D model

The annotation phase is aimed at the compilation of an application (3DHOP) for the navigation of informed 3D

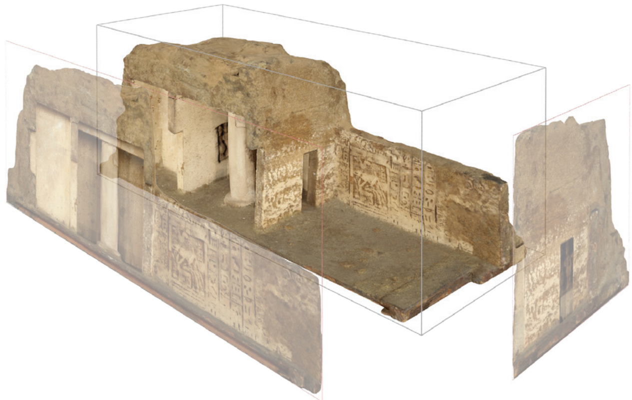

Fig. 8 - Beit el Wali, digital relief of the model (dimensions of the two halves 51 x 68 x 29 cm). Construction of the images by projection on the bounding box

Fig. 9 - Elevation and cross-section of the surveyed model

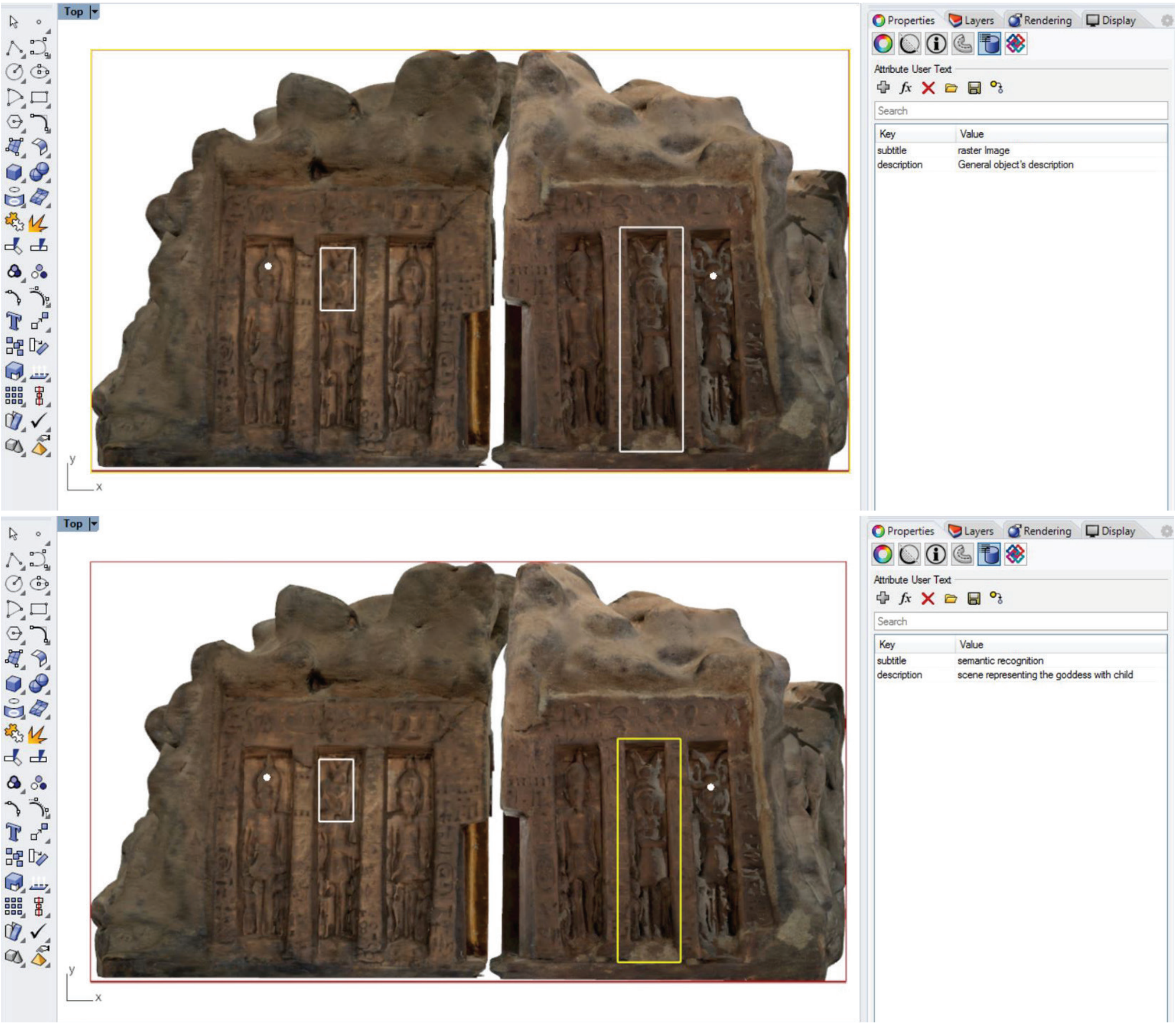

Fig. 10 - Annotation of geometry is done by following a hierarchy

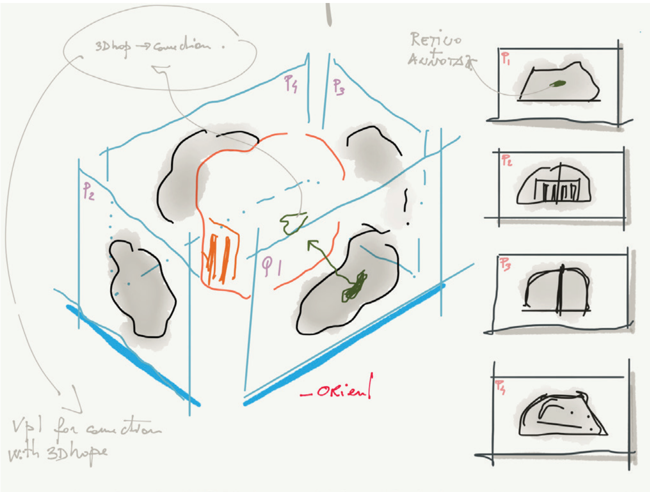

Fig. 11 - Remapping of the geometries and information from the 2D image to the acquired 3D model

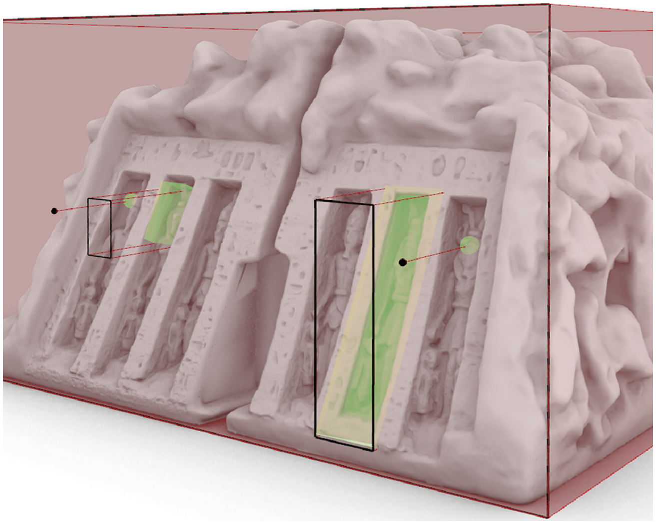

Fig. 12 - Remapped geometry from the picture, then projected on 3D model

models in a web space, the application combines the morphological data and the historical and artistic data of the examined models. Therefore, the attributes previously associated with flat images of the chosen subject, must be reported on interactive punctual or volumetric geometries capable of providing the information collected. The mapping phase foresees an implementation of the annotations made in 2D without dispersing the data collected in the previous phase, information that will be activated when the user selects the interactive elements created (hotspots) in the web portal. Remapping of the geometries and information from the 2D image to the acquired 3D model is done using typical NURBS operations[9] and Descriptive Geometry[10] (Figure 11)

The synthetic algorithm of the whole process foresees the orthogonal projection of the acquired object on the faces of the boundary parallelepiped that circumscribes the detected model; then the faces of the parallelepiped are oriented on the horizontal plane and saved separately. The image is textured on nurbs surfaces that are equipped with an internal two-dimensional reference system with two variables: u, v. Each annotative element can therefore be related to the two-dimensional system in the plane that will be transferred directly on the faces of the parallelepiped and then projected perpendicularly to the faces on the scanned 3D model. Each annotative element, during the transformation from the plane to the space, carries with it the original ID reference that connects it to the information database (Figure 12); this happens for the areal and punctual annotations.

Parametric tools for implementing 3DHOP HTML code

Code for the graphic construction of the web portal consists of one part for the implementation of the portal layout and another part for the implementation of information on annotative objects.

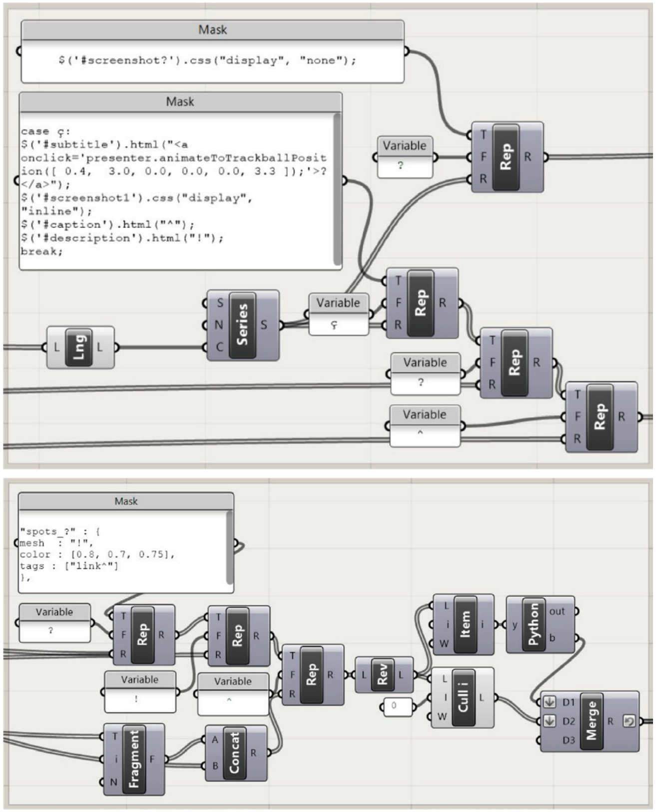

Fig. 13 - Textual mask structured according to the html syntax to create the consequentiality of the code parts

This last part can be defined as "parametric" because it is influenced by the number of annotations made on the images. As the number of annotations increases, the length of the code that manages the 3D objects of the portal varies, linking them to the notes described by the expert. For this reason, the basic code for the construction of the portal can be grouped in the following parts:
1. the part dedicated to the organization of the user interface layout;
2. the part describing the attributes and behaviours of the models in the scene.
The portions of code belonging to the second point, once mapped in relation to the basic syntax, can be replicated in relation to the number of annotative objects previously collected and associated in the CAD environment.
Through the use of the VPL language, a textual mask structured according to the HTML syntax has been created. The mask is composed of code fragments to be repeated in relation to the number of annotative geometries introduced. Special characters are placed inside the code as placeholders to identify the variables in which to place progressive elements to create the sequentiality of the parts of the code (Figure 13).
At this time the code is proposed as an open VPL diagram that allows the usual changes and updates during the research phase; once validated the procedure on several case studies, the code will be grouped into individual components in order to become an add-on for the VPL, which will be used for future operations of interrelation between CAD space and web portal. The result of the automation of the annotative enrichment phase, allows the almost complete compilation of the part of the code delegated to describe the attributes and behaviours of the models in the scene, generated by the 2D annotations.
Conclusions
The described procedure proposes innovative actions for the communication and dissemination of culture through digital products. The innovative aspects are mainly aimed at the application of informed modelling procedures for small-scale, non-architectural objects generally contained in museums. The possibility of digitizing the container and the content triggers a dialogue that has repercussions on the management and design of spaces and museum installations. The acquisition and the numerical representation of the shape has a sure consequence on the conception of installations that exploit technologies of Augmented Reality (AR) and Virtual Reality (VR)[11].
Adding information to the shape allows us to interact

with the invisible values of the works. The invisible values we are talking about are generated over time and derive mainly from the historical and artistic vicissitudes of the digitised artefact. Values are not only a legacy of the past, but also the present proposes new indicators from social networks or the media in general; invisible properties become as important as the formal values of the work. The weighted relationship between these values introduces an attractive index to be used in the exhibition design of museum spaces[12]. In addition to communication and the design of cultural contents, the proposed procedure allows to renew the management aspects of the works. Among the data connected to the model there are also those for the museum's operators, which can be accessed from the object sheets[13]. These contain the logistical information but also the parameters that guarantee the well-being of the work within the exhibition spaces. The presence in the digital environment of data relating to the contents (Collection Information Modeling) and the container (Building Information Modeling) allows the creation of evaluation algorithms to support the setting up of temporary exhibitions.

Notes

[1] Cf. Patrucco et al. 2018; Kersten et al. 2018.

[2] Cf. Guidi et al. 2017; Di Pietra et al. 2017; Adami et al. 2015.

[3] Cf. Rechichi and Fiorillo 2019.

[4] Cf. Lo Turco et al. 2018a.

[5] Cf. Rechichi and Fiorillo 2019.

[6] Cf. Patrucco et al. 2018.

[7] Cf. Kersten et al. 2018; Guidi et al. 2018; Gajski et al. 2016.

[8] Cf. Lo Turco, Calvano, Giovannini 2019.

[9] Cf. Di Marco 2017.

[10] Cf. Migliari 2008.

[11] Cf. Luigini, Panciroli 2018.

[12] Cf. Lo Turco, Calvano 2018.

[13] Cf. Manoli 2015.

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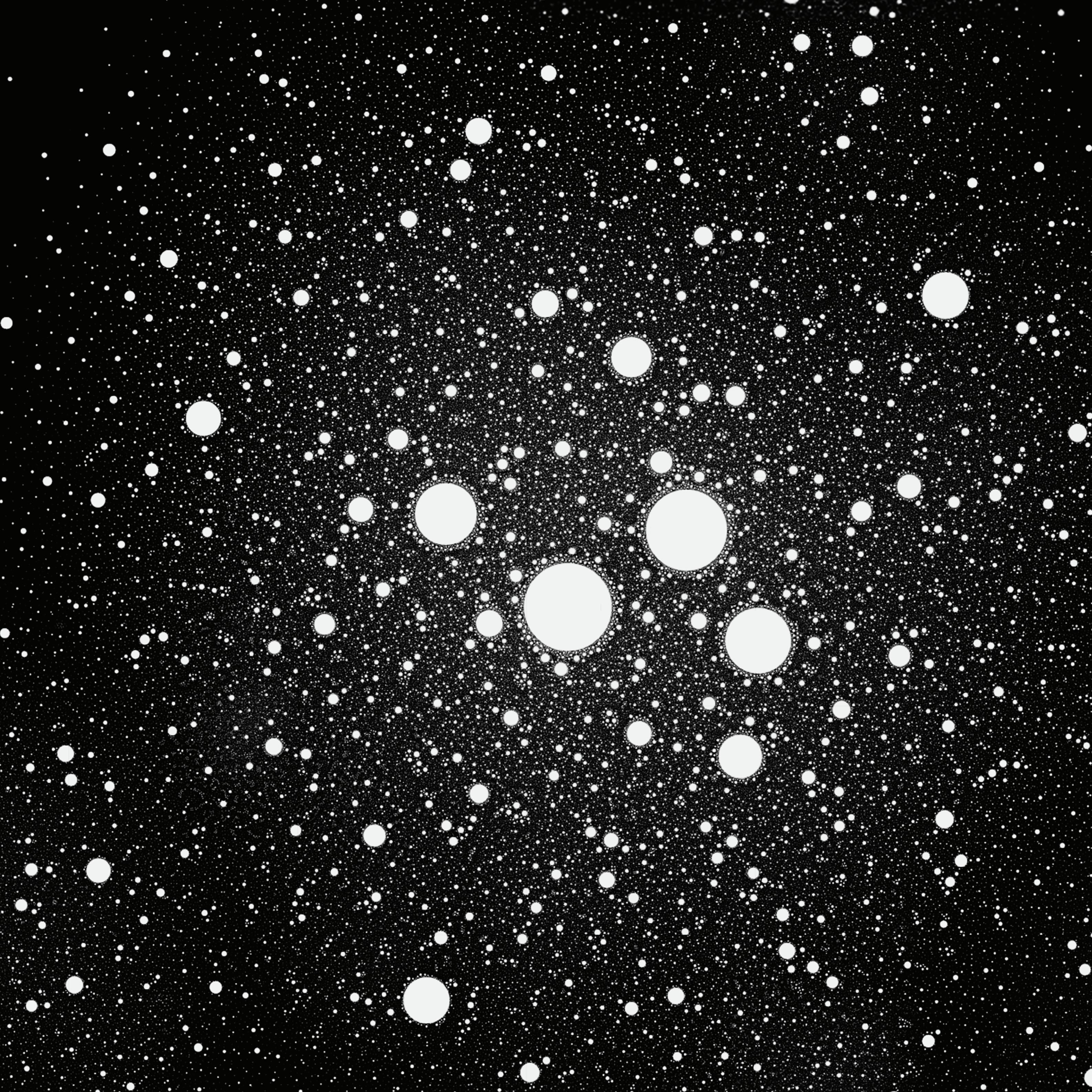

PART II

DATABASES, SEMANTICS & INTEROPERABILITY

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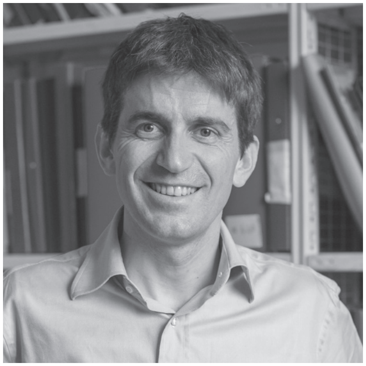
She is Marie Curie supervisor. She won the title of "Matteo Dellepiane Best Paper Award" at ISPRS/CIPA Workshop 3D-ARCH 2019.



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He teaches drawing, survey and digital modeling in bachelor and master courses in Architecture, in particular focusing on international students, and on digital methods in the courses "New technologies for survey and drawing" and "GIS and 3D for cultural heritage"

DIGITAL VISUALISATIONS OF CULTURAL HERITAGE

Laura Inzerillo, Paolo Piumatti

The wide-spreading of digital visualisation of Cultural Heritage arises some questions regarding the sustainability of the digital ecosystem necessary to such purpose. Modern digital visualisation in fact strongly relies on 3dimensional information and models, and currently digital 3D modelling is affected by some critical issues, such as the non-negligible effort to produce 3D models, their reliability and scientific transparency, the obsolescence of file formats and the full exploitation of 3dimensional information.

Until a few years ago a considerable effort, reported in many scientific papers, was dedicated in the creation of 3D models that were increasingly more complete, detailed, accurate and realistic, and in the optimization of such effort. As a result, today several tools and techniques, even low cost, are available to produce 3D models with a high level of detail and accuracy. So, while the importance of the first issue listed above is decreasing, other issues call the attention of scholars. In the last decade the awareness of the importance of documenting the reliability of a 3D model is arising, as summarized in the London Charter[1] (2009) and its wider acceptance. As a consequence, for scholars, documenting the human processes of understanding, interpretation and modelling has become crucial to assess the scientific value of digital models. Such change of paradigm is well summarized in these words of Diane Favro, who directed the Rome Reborn project "I would argue that the real value of historical simulations lies not in the representations themselves, but in the process of their creation and in the subsequent experiments now possible to be conducted within the simulated environments. Even if digital representations are not true, if well conceived, they expand our methods of investigation, the aspects we consider and our overall understanding of historical environments"[2].

The documentation of the modelling process today finds a new approach in the procedural or parametric modelling, that ensures the transparency of the modelling process embedded in the model itself. In addition to this, procedural modelling partly addresses the problem of obsolescence of file formats, since the output model is the result of transparent and explicit instructions that could be replicated in the future and adapted in new platforms. This addresses one of the main problems of traditional 3dimensional models, that are static, difficult to implement and with a limited life cycle.

Finally, the enrichment of 3D models allows them to overcome their full exploitation. A 3D model enriched with linked information is no more only a support to other ways of communication, but is the main way of communication.

For this reason, in this session these topics are addressed:

- transparency, reliability and enrichment via the organization of knowledge using ontologies and their connection with building information models;
- optimization of 3D model production via advanced digitisation and building information modelling;
- innovative exploitation of 3dimensional information via a better interaction of user and Virtual or Augmented Reality.

Franco Niccolucci in "*Ontologies and semantic structures for*

Cultural Heritage" provides a comprehensive yet concise overview of the CIDOC CRM, an ontology to organize the knowledge about cultural heritage. For this reason, and given the vast experience of the author, the chapter is extremely useful and clear for novices and experts alike. It allows us to understand the basic concepts underlying the concept of formal structures and ontologies and offers some useful examples to clarify the concept. Finally, it offers a valuable perspective on the challenge of combining the semantic approach with Building Information modelling and in particular with Heritage BIM.

Federica Maietti and Marcello Balzani in "*Data acquisition protocols and semantic modelling of the historical-architectural heritage: the INCEPTION Project*" give an overview of a recent project that aimed to connecting semantic information to geometric 3D models and developing an open-standard Semantic Web platform for accessing, processing and sharing interoperable digital models.

Bruno Fanini in "*Applications of a compact session encoding for immersive WebVR analytics*" focuses on Cultural Heritage fruition in Virtual Reality through the use of head-mounted displays (HMDs) and the Web. After an interesting and concise introduction to WebVR to familiarise novices to the topic, the chapter focuses on a very specific topic: the analysis of VR sessions and the optimization of the registration of user interactions during VR sessions. As a result the chapter is of interest not only for IT scientists (the description of the specific methodology), but also for a wider audience of curators and researchers, since it enlightens the possibility to improve the digital Cultural Heritage fruition via monitoring user behaviour.

Valerio Palma in "*AI: architectural intelligence. Deep learning and heritage environments*" addresses a wide and actual theme: the use of Artificial Intelligence for the automatic recognition of architectural remains. While automatic recognition is an established feature in other domains, in the case of archaeological buildings it is still limited. The chapter illustrates an ongoing project that is developing a smartphone app to recognize monuments; it provides a concise introduction on deep learning models and convolutional neural networks and describes the first tests and case study.
These four points of view and experiences are tiles of a wider mosaic, they are innovative yet partial steps in a broad process towards a richer, easier, more comprehensive and dynamic exploitation of digital visualisation for Cultural Heritage.

Note

[1] http://www.londoncharter.org/

[2] Favro D. (2012). Se non è vero, è ben trovato (If Not True, It Is Well Conceived) Digital Immersive Reconstructions of Historical Environments. *Journal of the Society of Architectural Historians*, Vol. 71, No. 3, Special Issue on Architectural Representations 1 (September 2012), pp. 273-277.

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04 ONTOLOGIES AND SEMANTIC STRUCTURES FOR CULTURAL HERITAGE

FRANCO NICCOLUCCI

Abstract

The paper describes a formal structure to organize the knowledge about cultural heritage, i.e. an ontology. The main concepts of the reference ontology, the CIDOC CRM, are outlined. The CRM is compared with another method for documenting cultural heritage based on BIM and a possible convergence of the two methods is discussed.

L’articolo descrive una struttura formale per organizzare la conoscenza sul patrimonio culturale, cioè un’ontologia. Si introducono i concetti principali dell’ontologia di riferimento, il CIDOC CRM. Il CRM è poi confrontato con un’altra metodologia di documentazione del patrimonio culturale basata su BIM, e si esamina una possibile convergenza dei due metodi.

Introduction

The perception of cultural heritage is based on the mental model one has of it, a model that is influenced by a multiplicity of social factors: education, individual or community culture, past experiences, and so on. Thus, notwithstanding the attempts of choosing common parameters to define what is cultural heritage, subjective factors, belonging to individuals or to specific communities, always participate in what distinguishes cultural heritage from plain objects[1]. This may seem obvious when referred to purely intangible manifestations of cultural heritage, while for material assets, as for example in the case of monuments, their appearance obviously plays a major role. This has led some to base a formal representation of such assets starting from its shape, and attaching on it as attributes the description, the history and any other related feature. Paraphrasing Plato[2], one might object that the nature of a flute is not its shape, but the music that it produces. Thus, a flute is represented from a description better than a picture: although a popular adage states that "*a picture is worth a thousand words*", it's the wording that explains what that picture is about and what it means, its signification. A formal description of an object may start from its shape and attach to it the related concepts as attributes; or start from the concepts and consider the shape as an attribute. Although for material assets the two approaches are roughly equivalent, for immaterial ones the shape-based approach fails, as there is no shape to start with. Therefore, it introduces a dangerous and inappropriate distinction among cultural assets – material, where it works; and immaterial, where it doesn't – which is better avoided adopting the other approach, summarily outlined in the present paper.
The science that organizes knowledge about such significations is called Semantics. It deals with concepts organized as *classes* (also called entities) and *properties* (also called relationships) relating them. A class is equivalent to a concept, the abstraction of specific samples; the real things belonging to that abstract category are called *instances* of the class. An organized system of classes and properties used to describe a conceptual model of a universe of discourse is called an *ontology*. An ontology has an internal hierarchy of more general concepts (*superclasses*) and more specific ones (*subclasses*).
Relationships between classes create a network that represents the structure of the knowledge about a general item, and once it is instantiated, i.e. applied to a specific item, it represents the knowledge about it. For example, let us consider the classes *Artwork* and *Actor* (i.e. a person doing something) and the property *was-made-by*. The general structure can be stated as *Artwork was-made-by Actor*; one of its many instantiations, e.g. the one concerning the David statue, would be: *Artwork* "David" *was-made-by Actor* "Michelangelo".

The CIDOC CRM

The ontology for cultural heritage is the CIDOC CRM[3] (Conceptual Reference Model). It is an official ISO standard (ISO 21127:2006). Conceived as common and extensible semantic structure for cultural heritage documentation, it was born in 1999 as an ontology for museum collections under the aegis of CIDOC[4]. The CRM is managed by an international Special Interest Group deciding by consensus and led by Martin Doerr at FORTH in Crete, Greece.
The CRM originally managed the museum documentation, but thanks to its extensibility it grew in time to manage the documentation of archaeological excavations (CRMARCHEO), digital objects (CRMDIG), archaeological standing structures as the Coliseum, the Parthenon and so on (CRMBA), and several other subfields. Therefore, it is inappropriate to consider it just museum matter, as sometimes it happens to hear; rather, the CRM is an evolving, expandable system of ontologies compatible with each other and interoperable, tailored to the

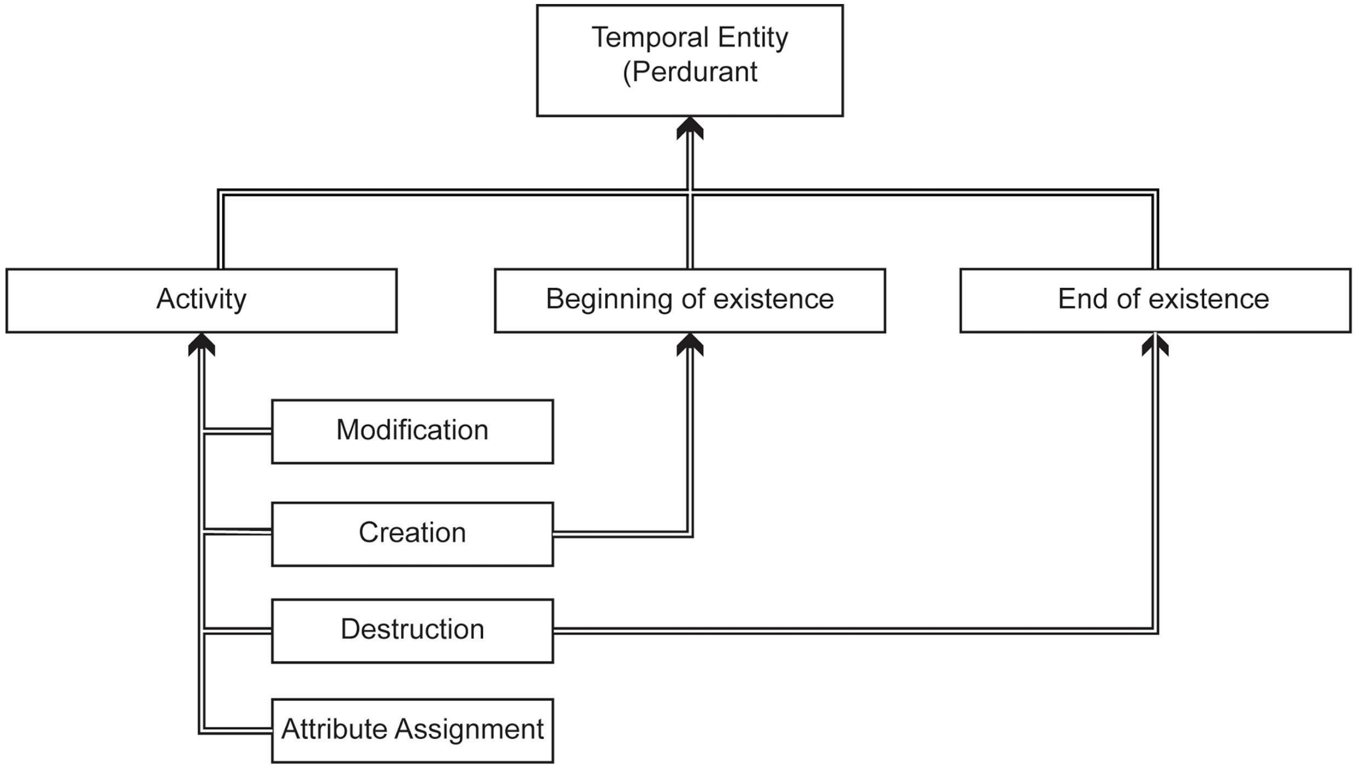

Fig. 1 - The hierarchy of temporal entities

documentation of cultural heritage.
The CRM includes a substantial number of subdomain extensions, i.e. classes and properties added on top of its base structure to address specific subdomain issues, as the ones mentioned above. This minimal CRM includes 37 entities and 36 properties, which must be incorporated in every CRM extension to be compatible; actually, more are necessary for the extension to be usable.
A global classification of the CRM entities distinguishes among:
Temporal entities (also called *perdurant*): they include all phenomena that happen within a given time interval, for example events and activities.
Persistent entities (also called *endurant*): they include all physical or conceptual objects that have a definite identity for all their existence, e.g. people, documents, ideas.
Space-temporal volumes: these are sets in the 4-dimensional space *x*, *y*, *z*, *t*, i.e. the physical space plus time. For example, a city occupies a space-temporal volume as it changes the space it occupies during time. The combination of the space occupied at different time instants throughout all the city existence forms the space-temporal volume of the city.
Abstract entities: time, place, dimension.

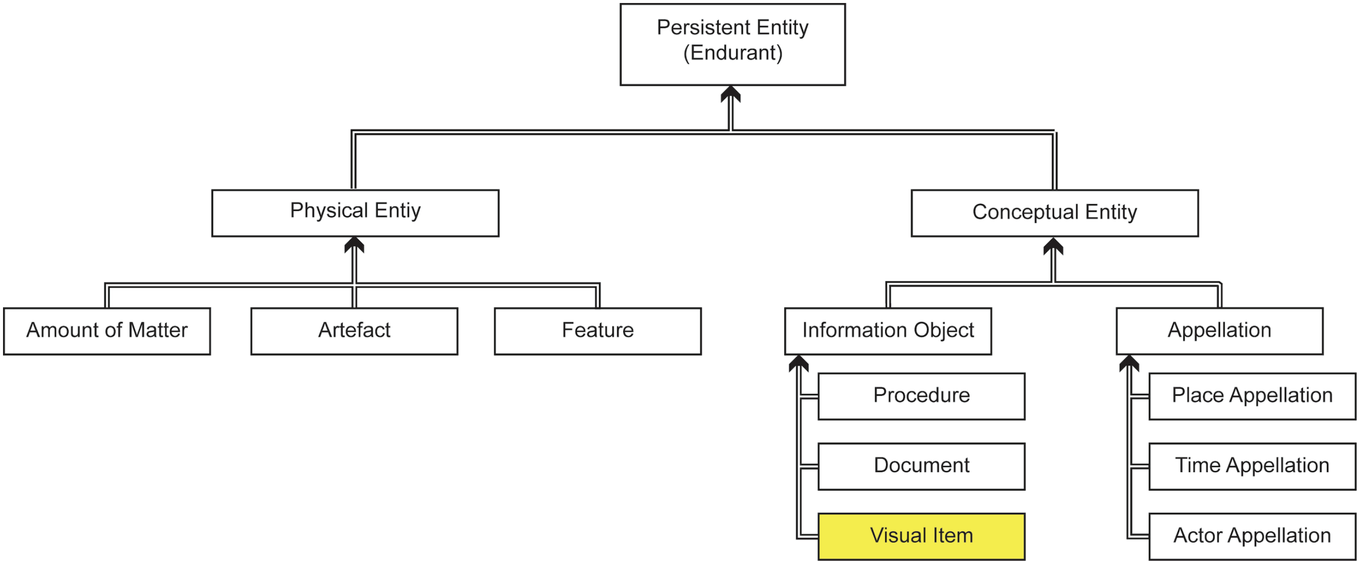

Fig. 2 - The hierarchy of persistent entities. Visual items are evidenced at the bottom.

Values: for example, a number or a character string. These are outside the scope of the CRM.

Conventionally, entities names are capitalized, and property names are not. Here we will also *italicize* both types of names.

Perhaps the most important general property is "*is_a*". X *is_a* Y means that all the instances of X are also instances of Y; in other words, X is a subclass of Y, and Y is more general. For example, bridges are constructions, so if B is the class of bridges and C is the class of constructions, B *is_a* C. In diagrams, the *is_a* property is represented by a double-line arrow going from the more specific to the more general, in the above definition from X to Y. The "*is_a*" is a general property that belongs to any ontology and therefore is not explicitly declared as such, it is incorporated in the concept of subclass.

Figure 1 represents the hierarchy of (main) temporal entities.

As shown, a *Temporal Entity* can be specialized as an *Activity*, i.e. a deliberate action by a person or a group, which can be further specialized in different kinds of activity including among others the assignment of an attribute, for example a name. An activity affects objects, i.e. persistent items, in several possibly ways, and this is represented through properties (not shown in the figure) like the property *modified*, linking the *Modification* activity to the object that was modified.

Figure 2 shows the hierarchy of Persistent Items.

As shown, *Persistent Items* may be *Physical* or *Conceptual*.

A *Physical Entity* may be an *Amount of Matter*, i.e. undifferentiated stuff; an *Artefact*, something deliberately created by humans, in the CRM called *Physical Man-Made Thing*; or a *Feature*, i.e. some characteristic of an item which cannot exist by itself but only in relation to that item, like a scratch on an object. For the sake of simplicity, not all subclasses are shown in the figure: for example, the

hierarchy leading to *Person*, which is a *Physical Entity* (or *Physical Thing*, as named in the CRM), is not represented.
Conceptual Entities (called *Conceptual Object* in the CRM) consist in *Appellation*, i.e. names, and *Information Objects*, which carry information about something. The latter among others include *Visual Item* i.e. a visual representation of something, like a drawing, a photo, a 3D model, and so on. Also, for this hierarchy the figure is simplified.
An important characteristic of CRM is to describe reality through a sequence of events. For example, the statement "Michelangelo sculptured the David with Carrara marble" would be described as follows:
Actor "Michelangelo"
performed
Production
employed
Material "Carrara marble"
produced
Physical Man-made Thing "statue"
has title
Title "David"
used general technique
Type "sculpture"
used specific object
Thing "hammer"
used specific object
Thing "chisel"
Thus, Michelangelo is represented as the performer of a *Production* activity, which is a *Temporal Entity*. This activity (not Michelangelo!) produced the statue and also all the details, like the material, the technique and so on, pertain to the activity.
The above example shows that the concept of *Event*, or possibly its subclass *Activity* – an action intentionally carried out, while an *Event* may be unintentional as an earthquake – is the cornerstone of the CRM. Although at first sight this might appear as a complication, it is instead a very logical and precise method of describing the universe (of cultural heritage) as the result of events.
What is more important, the CRM describes everything as a *triple*, an expression of the form subject–predicate–object. This allows the description of complex relationships, which on the contrary is not possible when the metadata structure is a "flat" schema of labels and values, without any internal interrelation. In such cases it is not appropriate to call such schema the "semantics".
This triple approach allows implementing CRM using RDF[5] and availing of powerful RDF-based tools for semantic searches in triple-store databases.
A final note concerning the CRM notation: the CRM puts a number in front of entities and properties as in *E7 Activity* or *P126 employed*. For the sake of simplicity, such numbering was not used in this paper.

A CRM implementation: the ARIADNE catalogue

ARIADNE[6] (2013-2017) is an EU-funded infrastructure project for the integration of archaeological datasets. Its continuation ARIADNEplus has been funded until December 2022. It starts from the consideration that a huge number of archaeological data are available in online repositories, but since the latter do not communicate with each other there is an extreme fragmentation that prevents an effective use of such important resources. Additional fragmentation derives from the data creation and management, which are usually based on modern administrative regions that do not correspond to past ones: for example, data about the Roman province of *Gallia* are split between Italy, Switzerland, France, Belgium and possibly more; finally, texts are in many different languages. The goal of ARIADNE is to overcome such fragmentation through a catalogue that links all such data repositories and allows a one-stop point for searching their metadata. The current search functionality of the catalogue is based on facets such as Time, Space, and Object. Free text searching is also allowed.

ARIADNEplus will go further into integration. It will create an archaeological cloud and VRE[7]. Structured repositories as databases and GIS will have a deeper, item-based integration, while metadata for textual documents (a large majority of the whole set) will be enriched by NLP[8] and data mining.[9]
ARIADNE is mentioned here because its implementation is based on the CRM. The catalogue uses a CRM-compliant ontology named AO-Cat. Extensions for various archaeological subdomains, as environmental archaeology, archaeometallurgy, archaeological standing structures, and so on (14 subdomains in total) are in progress.

AO-Cat picks a small number of entities from the CRM, and of course avails of all others. The chosen ones are renamed to make their use simpler for non-technical users, the archaeologists. A short description of the main entities follows.
The top class for data in AO-Cat is called *ARIADNEResource*. It is any item present in the ARIADNE infrastructure, including catalogue content and services. Its subclasses are *ARIADNEData*, distinguished into
IndividualDataResource: a dataset with any content
Collection: a grouping of datasets referred to a common theme, for example a report on a monument, the photos and drawings of the monument, and so on.
Service: software available in the ARIADNE framework.
Types are provided by the class *ARIADNEConcept*, which is a taxonomy of all topics involved with ARIADNE. For example, an individual data resource may be about a specific monument. This is expressed via a property *is_about* and the *ARIADNEConcept* "monument".
Events are described using the class *ARIADNEEvent* and its subclass *ARIADNEActivity*. They correspond to the homonymous classes in the CRM, and are used for events and activities of interest to ARIADNE on which there is enough information. For example, the documentation of a vase found in an excavation will not describe its creation activity, which is likely to be unknown, but the activity of discovering it in the excavation. People, i.e. individuals, teams and institutions, are recorded as *Agent*, the equivalent of the CRM *Actor*. The whereabouts of any resource or event are described in *TemporalRegion* and *SpatialRegion*.
A number of properties connects classes with each other, as required. Among them, for example, the already mentioned *is_about*; *has_ARIADNE_subject* (which is an *ARIADNEConcept*); *has_name*, used for *Agents*; *has_period* and *has_spatial_region* to locate an event in time and space; and a few more.
It is important to note that each AO-Cat class or property exactly corresponds to a CRM class or property: as already mentioned, the renaming was made only to facilitate users. This compatibility makes the system fully interoperable with CRM-compliant databases.
The AO-Cat example shows that it is possible to apply the CRM in a very simple and user-friendly way to any domain in cultural heritage.
In other cases, the addition of new concepts is required. This happens, for example, in CRMBA, the CRM extension to archaeological standing structures[10]. This extension requires to introduce a new class *Built Work* to represent it; built works are "*buildings, components of buildings, complexes of buildings, other structures, or a man-made environment, typically large enough for humans to enter, serving a practical purpose, being relatively permanent and stable*", as defined by AAT[11]. A functional unit of *Built Work* is termed *Morphological Building Section* and may consist in the roof, a stair, the foundations, and so on. Such functional unit may be a *Filled Morphological Building Section*, as a wall, or an *Empty Morphological Building Section*, a part of the building confined by *Filled Morphological Building Section*s but having its own identity, like a courtyard, a room, a portico, and so on. Appropriate properties have also been introduced, e.g. *is section of* to relate a *Building Section* to the *Built Work* it belongs to; *is connected to*, to

connect two *Building Sections*; and *is connected through*, when the connection is through another section.
When a new class is created, it is inserted in the CRM hierarchy, for example *Built Work* is a subclass of the CRM *Physical Man-Made Thing* class that it specializes, so *Built Work is_a Physical Man-Made Thing*. If one needs to search e.g. for stone objects, both buildings and others, the system may easily be instructed to look into *Built Work* or into the more general category *Physical Man-Made Thing* when such specialization does not exist.

The semantic approach vs BIM and HBIM

BIM[12] is "*a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.*"[13] The IFC[14] data model provides an open specification for BIM. The application of BIM to heritage buildings, called HBIM (Heritage BIM), may have different interpretations and applications[15]. A notable one is the use of BIM for conservation works on historic buildings, recommended by Historic England[16]. Often BIM is considered a 3D modeling tool availing of smart libraries of 3D objects for the architectural components, and with the option of adding metadata in a linked database. A serious hindrance, however, is the lack of synchronization between such database and the modeling tool; IFC tries to address this issue. Existing tools allow only a very simple metadata structure with very little or no semantics[17]. Hence there is still a divide between the BIM (and 3D) world and the semantic approach as the CRM one: both methodologies in practice disregard the other one. For the CRM, a 3D model of the building is just a *Visual Item* attached to its documentation. For the various flavours of BIM and HBIM, metadata often reduce to a flat list of attributes with no semantic structure. Semantic annotations of 3D models have been addressed in Acierno et al.[18] and in Messaudi et al.[19]; both, however, still use the 3D model as the root concept, what is not totally convincing for the reasons stated in the Introduction.
In sum, there is a strong need of integration to reconcile the two perspectives, at present opposite but hopefully integrated and interoperable in the future. For BIM, the incorporation of semantics and RDF has been the subject of a recent paper[20] which builds on IFC to express metadata in RDF. It would be interesting to apply a similar approach to HBIM with reference to the CRM, the standard for cultural heritage documentation[21].

Notes

[1] A famous example, is Uluru in Australia, also known as Ayers Rock. This iconic monolith represents for Western tourists little more than a natural and attractive curiosity. For the aboriginal people living in the area, it is instead a sacred area with a number of taboos concerning the visit of the surrounding zone and the prohibition of climbing over the hill.

[2] Plato, *Republic*, 10.601e.

[3] Official web site: https://cidoc-crm.org

[4] CIDOC (Comité International pour la Documentation) is the International committee of ICOM (International Council of Museums) in charge of the documentation of cultural assets.

[5] RDF: Resource Description Framework is a standard model for data interchange recommended by W3C. See: https://www.w3.org/RDF

[6] ARIADNE: Advanced Research Infrastructure for Archaeological Dataset Networking in Europe. ARIADNE and ARIADNEplus were both funded by the European Commission under the Community's Seventh Framework Programme and Horizon2020. Project web site: https://www.ariadne-infrastructure.eu

[7] VRE: Virtual Research Environment, a virtual space for collaborative research enabled by access to data and the availability of software tools (services) to process them.

[8] NLP: Natural Language Processing.

[9] Cf. Niccolucci, Richards 2013; Meghini *et al.* 2017; Niccolucci, Richards, 2019.

[10] Cf. Ronzino *et al.* 2015.

[11] AAT: Getty's Arts and Architecture Thesaurus, https://www.getty.edu/research/tools/vocabularies/aat

[12] BIM: Building Information Modelling (the methodology) or also Building Information Model (the result).

[13] https://www.nationalbimstandard.org/faqs#faq1

[14] IFC: Industry Foundation Classes, maintained by BuildingSMART. https://www.buildingsmart.org/

[15] Cf. Pocobelli *et al.* 2018.

[16] Historic England 2017.

[17] Cf. Tobiáš 2016.

[18] Cf. Acierno et. *al.* 2017.

[19] Cf. Messaudi et. al 2018.

[20] Cf. Zhang, Beetz, de Vries 2018.

[21] All the web references mentioned in the paper and in the bibliography were consulted on 22 July 2019.

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05 DATA ACQUISITION PROTOCOLS AND SEMANTIC MODELLING OF THE HISTORICAL-ARCHITECTURAL HERITAGE: THE INCEPTION PROJECT

Federica Maietti, Marcello Balzani

Abstract

Advanced and integrated digitization of heritage artefacts, monuments and sites is one of the priorities stated at European level during recent events focused on next research avenues to record, document and preserve Europe's cultural heritage and foster its accessibility.
In this scenario, it is possible to identify different research approaches, addressing several aspects related to the development of databases and digital models; the state of the art at international level is articulated, complex and inter-sectoral, but it is possible to point out some common directions towards digitization strategies and data management. Parametric modelling, semantic enrichment and applications aimed at the immersive fruition of cultural heritage are some of the main research fields fostering new approaches to innovation of methodologies and tools.
New technologies, devices and digital environments are influencing the ways in which heritage contents are explored, used, managed and shared, also in citizens everyday life. In this framework, the project INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling, funded by the European Commission within the Horizon 2020 programme, develops key-targeted innovations in efficient 3D digitization methods, post-processing modelling tools, semantic web-based solutions and applications to foster a wide and aware access to digital Cultural Heritage.
The overall methodology is focused on Architectural Heritage, deepening the potential that the "architectural space" has in creating new connections and awareness in the field of cultural heritage.

La digitalizzazione avanzata e integrata di manufatti, monumenti e siti del patrimonio culturale è una delle priorità a livello internazionale, come dichiarato durante i recenti eventi della Commissione Europea incentrati sui prossimi percorsi di ricerca per rilevare, documentare e preservare il patrimonio culturale e promuoverne l'accessibilità. In questo scenario, è possibile individuare diversi approcci di ricerca che affrontano molteplici aspetti correlati alla messa a punto di banche dati e modelli digitali; lo stato dell'arte a livello internazionale si configura come articolato, complesso e intersettoriale, ma è possibile individuare alcuni orientamenti comuni nei confronti delle strategie di digitalizzazione e di utilizzo dei dati. La modellazione parametrica, l'arricchimento semantico e la fruizione immersiva del patrimonio culturale sono alcuni dei principali settori di ricerca che promuovono nuovi approcci all'innovazione di metodologie e strumenti. Nuove tecnologie, dispositivi e ambienti digitali stanno influenzando il modo in cui i contenuti correlati al patrimonio culturale vengono esplorati, utilizzati, gestiti e condivisi, anche nella vita quotidiana. In questo contesto, il progetto INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling, finanziato dalla Commissione Europea nell'ambito del programma Horizon 2020, sviluppa innovazioni mirate a un avanzamento nella digitalizzazione 3D, strumenti di modellazione e processamento dei dati, soluzioni basate sul web semantico e applicazioni per favorire un accesso inclusivo e consapevole al patrimonio culturale digitale. La metodologia complessiva è incentrata sul patrimonio architettonico, approfondendo il potenziale insito nello "spazio" nell'innescare nuove connessioni e nuove consapevolezze nel campo del patrimonio culturale.

Introduction

Nowadays, interest and commitment in the field of 3D digitisation of cultural heritage artefacts, monuments and sites is becoming ever increasing and crucial. Widespread threats due to natural deterioration, pollution, disasters, mass tourism, terrorism and vandalism, create an urgent need to make the most of digital technologies to record, document and preserve Europe's cultural heritage and foster their accessibility to European citizens[1].
A significant emerging trend at European level shows an increasing digitisation of immovable cultural heritage as well as initiatives to enhance cross-border cooperation and digital capacity in the cultural heritage sector.
Moreover, among most relevant needs in the field of heritage documentation, the importance of linked open data has emerged as a relevant topic to be further addressed along with technologies that can improve the quality of digitized material presented online.
In this context, standards or guidelines in 3D data capturing, documentation and data management are also seen as goals to be reached and further developed.
ICT standards, visualisation of and access to digital objects (metadata, graphical materials, etc.), interoperability, storage, use and long-term digital preservation to copyright, business models, findability, 3D digitisation and web statistics are additional research avenues to be implemented in the very near future[2].
In the above mentioned report on digitisation, online accessibility and digital preservation of Cultural Heritage, it is stated that library and archival materials are the main digitized resources together with museum collections, while an increasingly widespread digitalization of heritage buildings and sites is beginning (under EU initiatives and funding programmes) through 3D digitization activities.
This scenario, in addition to highlighting the need to apply digitization to the cultural heritage in an increasingly focused way, makes it possible to identify different research approaches, addressing several aspects related to data acquisition, documentation, modelling and management.
The state of the art at international level is articulated, complex and inter-sectoral, but it is possible to point out some common directions towards digitization strategies and data handling. Parametric modelling, semantic enrichment and applications aimed at the immersive fruition of cultural heritage are some of the main research fields fostering new approaches to innovation of methodologies and tools[3].
In this framework, the project INCEPTION - *Inclusive Cultural Heritage in Europe through 3D semantic modelling*, funded by the European Commission under the Horizon 2020 programme, aimed at developing 3D digitization methods, post-processing modelling tools, semantic web-based solutions and applications to foster a wide and aware access to digital Cultural Heritage.
The four-year project started in June 2015 and was completed at the end of May 2019. During the project development, the objective of carrying out simultaneously an approach based on knowledge and data interpretation, the needs of access to digital data by different types of users, and the implementation of specific tools were pursued.

INCEPTION overall methodology

The overall project development was set according to the following objectives:
Fostering collaborations across disciplines and technologies in Cultural Heritage field;
Proposing innovation in 3D data capturing procedures and 3D modelling (at heritage building and site scale);
Connecting to the geometric 3D model the necessary semantic information for in-depth studies and different uses;
Fostering the use of interoperable formats, making models interoperable, easily accessed, used and reused;

Developing an open-standard Semantic Web platform for accessing, processing and sharing interoperable digital models[4].
In order to reach the above-mentioned goals, three main research fields were faced: 3D data capturing, 3D modelling, data sharing.
After having set the project methodology or framework definition, the involvement of the Stakeholder panel and the identification of user needs were the starting point for starting activities related to documentation and data capturing. This section of the project led to the definition of the Data Acquisition Protocol and the development of a specific concept of an optimized 3D laser scanner firmware for 3D data acquisition. The concept is based on the general requirements of the workflow developed in the Data Acquisition Protocol for survey procedures of tangible cultural heritage.
In addition to provide a workflow for a consistent development of survey procedures, the definition of the Protocol allowed a consistent 3D digital data management toward modelling in BIM environment. Focusing on open standards (such as E57) for point clouds and open standard IFC for semantic BIM data managed by Semantic Web-based technology, the project foresees a long-term open access and interrelation of all available data.
BIM modelling and semantic modelling were developed simultaneously to the definition of the platform architecture. The platform aims at establishing a close connection between state-of-the-art architectural modelling technologies (BIM) and the latest cutting-edge web technologies. It is grounded on semantic web technologies and makes use of WebGL and RESTful APIs, in order to enrich heritage 3D models by using Semantic Web standards; this structure allows interlinking the platform with external available linked data and makes it gradually enhanced by further ontologies.
The main outcomes of the project, listed above, have been gradually applied and tested during the four years of development on nine Demonstration Cases in six European countries. These pilots have been selected in order to have a sample of different typologies of heritage buildings, covering different historical periods, a wide range of sizes and morphologies, different states of conservation, environmental conditions and different needs and requirements by Stakeholders.
The final step was related to the setting up of user-oriented tools based on data collected on the platform. Starting from existing systems, platform functionalities and external apps are indeed aimed at immersive experiences for accessing and understanding heritage sites.
The applied activities on Demonstration Cases allowed figuring out the practical application and analytic potential of resulting 3D multi-information models for research, interpretation, analysis and additional uses according to different purposes and users.
The digitalization of the selected Demonstration Cases was planned from the beginning in order to provide new approaches in studying, documenting, preserving, managing and communicating the architecture and its contents starting from the geometric knowledge obtained by 3D data capturing. The output 3D models allow data managing for scholar, professional, academic uses, up to multimedia visualisations and applications for site enhancement and for creating innovative ways to explore the architectural heritage and new forms of accessibility.
Starting from the survey and documentation, up to the data modelling, aggregation and uploading on the Platform, the INCEPTION procedure has been applied to all Demonstration Cases through the following activities:
Meetings and exchanges with the Stakeholders, to identify users, requirements and needs.
Development of overall survey and documentation process.
Application of the Data Acquisition Protocol by setting up a specific data management procedure.
Semantic enrichment of the 3D model in BIM environment[5].
Uploading and management of models, data and

information on the INCEPTION Platform, by setting a specific heritage workflow to be performed through the platform according to target users, needs and requirements. Development of user-oriented applications.

Data Acquisition Protocol

As already mentioned, the Data Acquisition Protocol[6] has been developed jointly to enhanced laser scanner. While the Protocol set up the guidelines for documenting Heritage sites, one of the main aims of the enhanced firmware was integrating metadata and paradata, developing 3D point cloud models linked to additional information and providing useful information for successive processing steps, such as H-BIM modelling, in a common and easy manner.
The Protocol[7] is a set of flexible guidelines ensuring data homogenization between surveys tailored on different requirements.
The initial assumption to the Protocol development was considering both site specifications and the uniqueness of each Cultural Heritage, and significances that can be documented on site or revealed in the available sources. The significances have been divided in nine categories (Spatial/metric-morphologic analysis, geometric significance; Aesthetic significance; Cultural-symbolic significance; Economic significance; Environmental significance; Historic significance; Risks; Social significance; State of conservation).
Specific activity indicators related to survey planning, performing and managing were then set up (Scan Plan; Health and safety; Resolution Requirements; Registration mode; Control network; Quality control; Data control and verification; Data storage and archive).
The Data Acquisition Protocol was the main source for the feature collections to be applied to the concept of the enhanced 3D laser scanner firmware. Most of the activity indicators were directly transcribed into functions to be covered by the firmware. Therefore, in addition to functions are already present in the existing firmware, a number of functions were identified as additional features to be developed and implemented as enhancements specifically for heritage sites survey[8].
In order to manage data capturing according to pursue a data capturing consistent to the aims of the survey, specific evaluation categories were set up. Starting to B up to A++ category, this classification includes four ranges of actions. From simple buildings or buildings for the creation of low-detailed BIM model, the category is “B”. For complex

Fig. 1 - Exterior and internal views of the Istituto degli Innocenti in Florence, the Italian Demonstration Case developed under INCEPTION

Fig. 2 - Internal views of the Istituto degli Innocenti in Florence

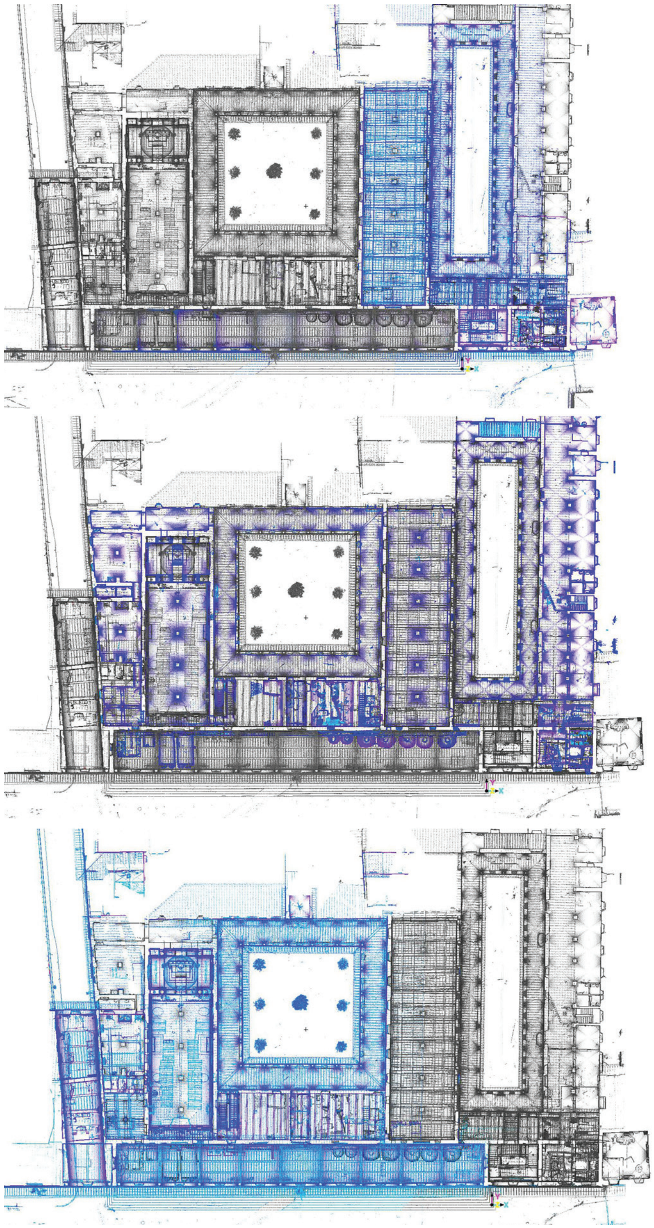
buildings or for surveys where the capturing process needs to be documented and traced, or for documentation that are the base for restoration projects, the category is "A++". For instance, the survey of the Istituto degli Innocenti in Florence, the Italian Demonstration Case, reaches the highest level (A++). This level achievement is due to the complexity of the building, to the set of significances embedded by the building by Brunelleschi[9], to the several technologies and techniques used during different survey campaigns and to integrated surveys in different times[10].
The digitalization of the Istituto degli Innocenti[11] and the development of specific applications within the INCEPTION project, can provide new approaches in studying, documenting, preserving, managing and communicating the architecture and its contents, not least the art collections and historical archive. According

to the Stakeholder requirements, since the Istituto has many tourist visits, main outcomes from INCEPTION are related to dissemination and enhancement of the three sections of the Istituto: history, architecture and arts. Future applications are not focused only on tourists but also on improved accessibility of history, architecture and arts contents for new studies of Renaissance architecture.

Data modelling and sharing under INCEPTION

Modelling procedures from 3D survey to BIM were implemented under INCEPTION. The definition of an open-standard format and semantic ontology to generate high quality, reliable and interoperable models of so-called H-BIM[12]. The starting point was the setting up of a procedure focused on the aggregation of geometries, significances, data and information into a BIM environment. An H-BIM ontology to model Heritage sites merging BIM and Semantic Web Standards into the INCEPTION Platform was developed. The H-BIM ontology allows identifying each building part through semantic concepts, allowing the connections to other Semantic Web entities and opening the building model to holistic enrichments. Using ontologies[13] opens up the opportunity to "layering" other ontologies, which means adding levels of machine-readable knowledge, and linking each component to external media files.

Connecting BIM environment and Heritage domain was faced by working with available tools and functionalities offered by W3C and where possible open source solutions. Semantic non-geometrical knowledge and semantic geometrical knowledge are split but interconnected, starting from IFC and IfcOWL[14]. BIM and Heritage are linked by adding a layer of mappings as typically applied with Semantic Web technology. The H-BIM is furthermore able to be enhanced by third parties extending, improving and adjusting the H-BIM over time and for different aggregations levels, allowing the INCEPTION platform to be



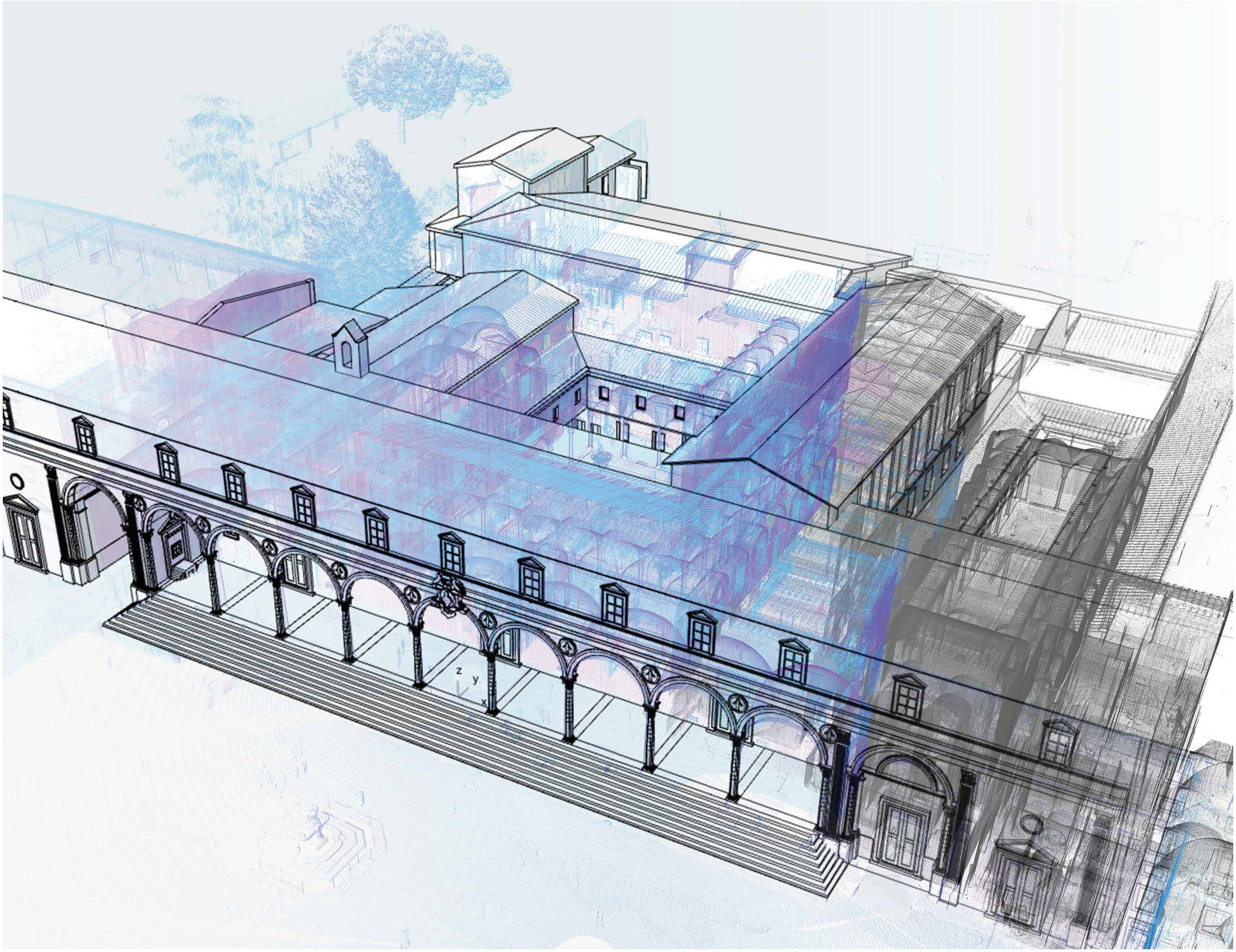
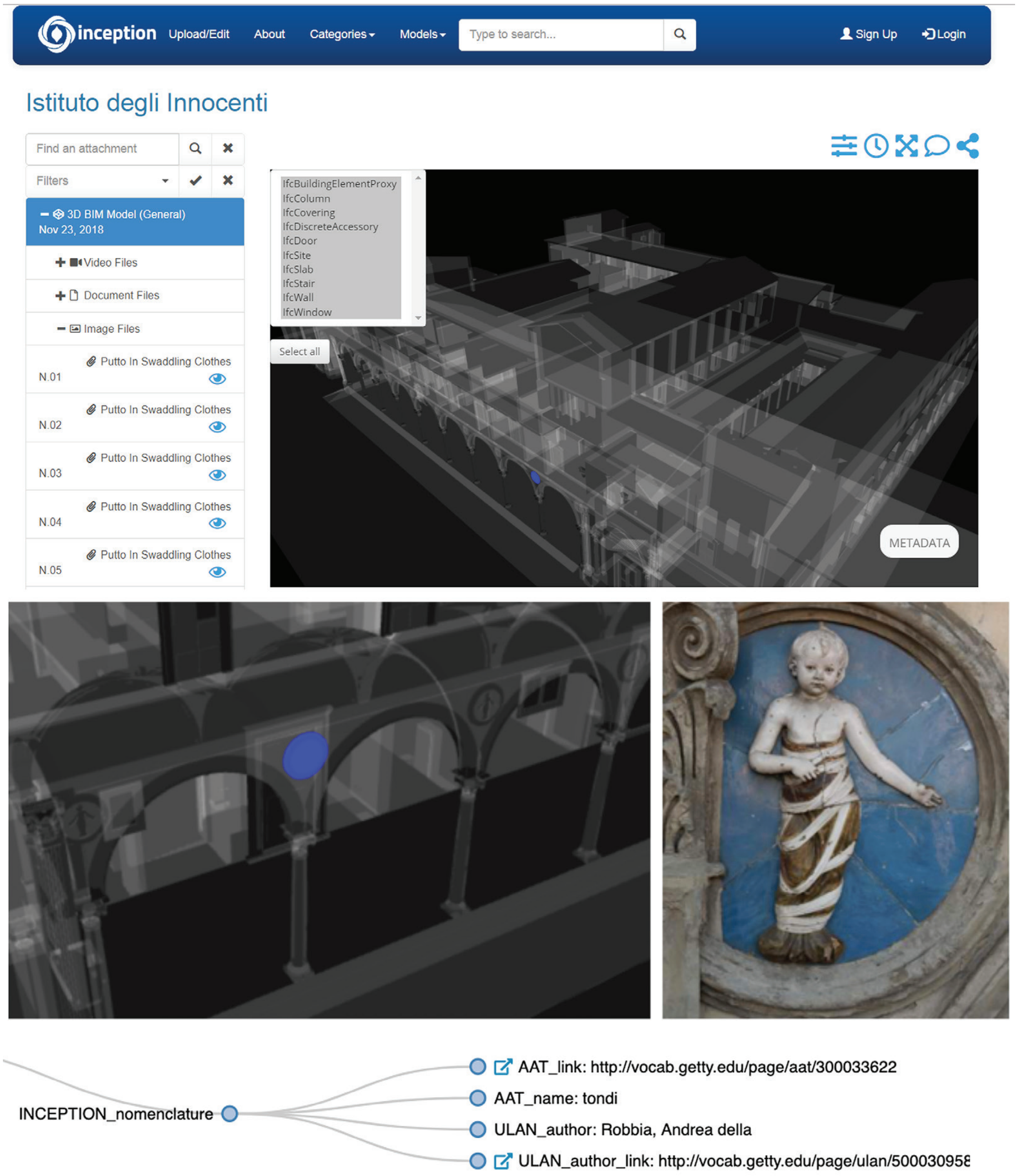


Fig. 3 - Planimetric views from the 3D database of three survey campaigns of the Istituto degli Innocenti in Florence

Fig. 4 - BIM model overlaying the 3D point cloud of the Istutito degli Innocenti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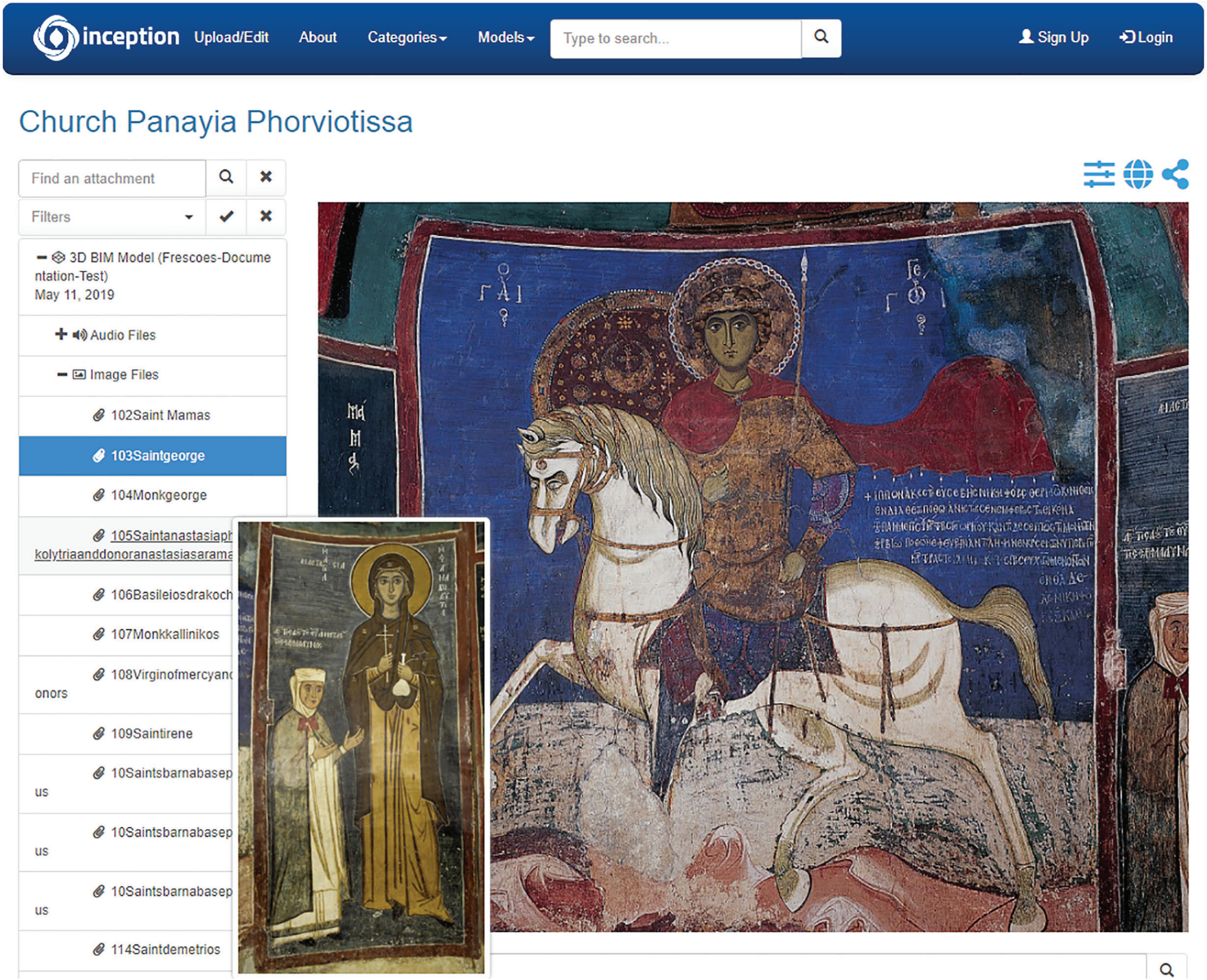

Fig. 5 - Screenshots of the INCEPTION platform. Decorations on the façade of the Istituto degli Innocenti. The metadata for a single 3D element span from physical properties (material, dimensions, etc.) to nomenclature

Fig. 6 - View of the platform functionalities applied to the Cypriot Demonstration Case. Image files related to the 3D model are displayed

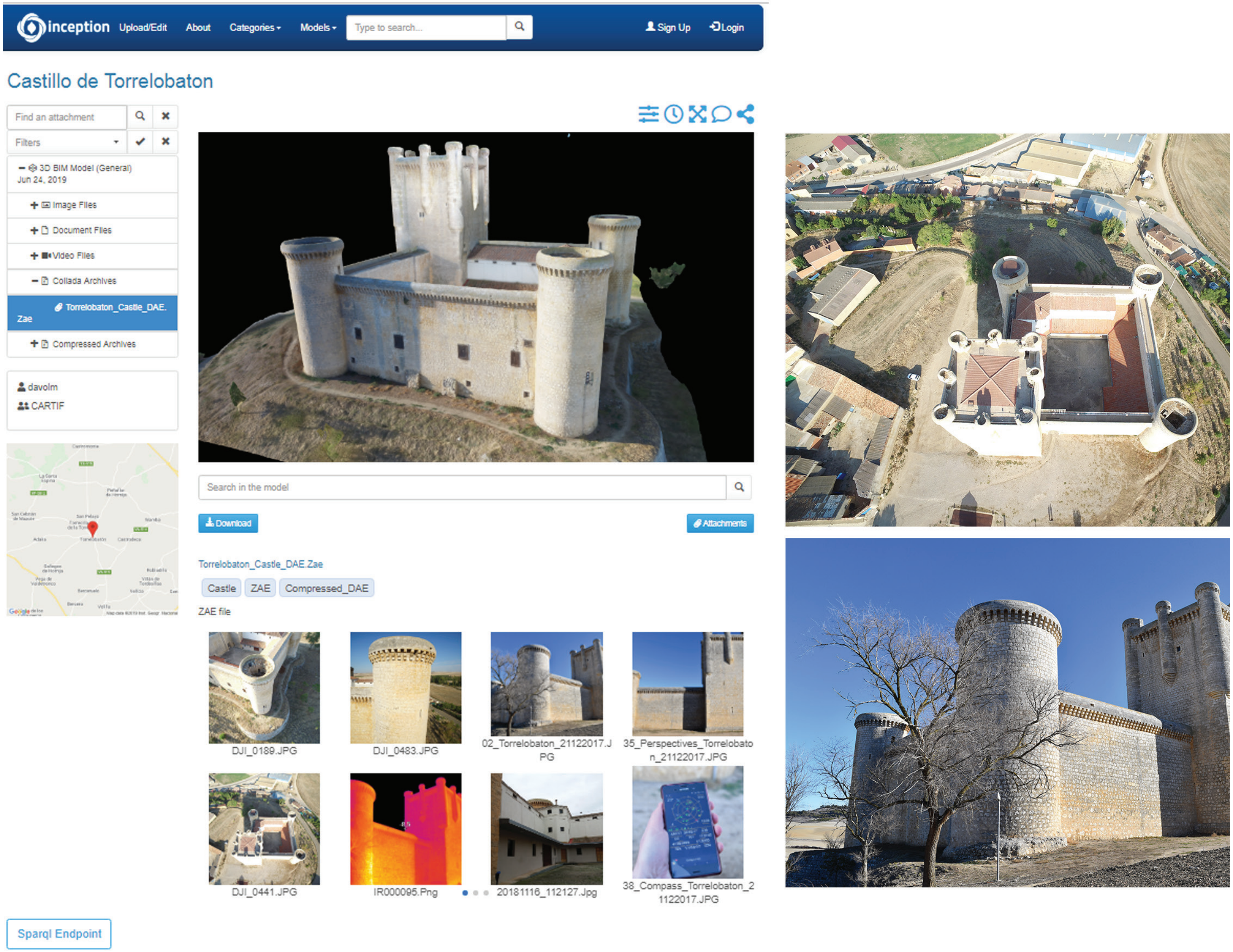

Fig. 7 - View of the platform functionalities applied to the Spanish Demonstration Case. One of the 3D model uploaded on the platform is a textured DAE model

flexible towards different views on how information should be stored according to the H-BIM ontology[15]. Therefore, the aim of the H-BIM ontology for the INCEPTION project is the capability to create, exchange and reuse information. In the cloud-based architecture, the main input is a BIM model of a Heritage site[16]. The development of an interoperable ontology allows aggregating information into the parametric model. The capability of the ontology to be linked with external open data or other ontologies is one of the main achievements. Therefore, the advancement proposed in model sharing under INCEPTION is based on core functionalities tailored on end-user needs, including developers and solution providers for interacting with external mobile devices and applications.

This orientation towards the end-users has been carefully verified during the development of the project thanks to the involvement of the stakeholders, who have actively contributed, from the third year onwards, also in identifying platform contents, user experience and interface. This helped focusing the main actions in browsing 3D digital models and interacting with specific information (according to different user categories) and developing platform functionalities.

Feedback from Stakeholders allowed stressing the current changing role of 3D digital models in representation of heritage and its analysis and collaboration across disciplines, providing semantic information for in-depth studies by researchers and users[17].

Conclusion and future developments

At the end of the project it is possible to emphasise that the main results, both at methodological and application level, have been achieved, putting together essential steps and workflows that can contribute to improving the documentation, survey, modelling, use and reuse of digital data applied to Cultural Heritage.

There is of course room for further developments and improvements, starting from the population of the platform following the INCEPTION procedure. Therefore, the conclusion of the project is not an end but a starting point.

The next steps, in the very near future, concern the application of the procedural protocols developed, in order to verify and test platform functionalities over a wide range of heritage digital models.

Following also the research directions expected in the coming EU programmes, next actions and follow-ups will be focused on fostering high quality, interoperable and open access to digital data to create higher digital engagement for different heritage fields.

Next steps will also connect project outcomes with emerging technologies such as big data, artificial intelligence and extended reality, by exploring new ways of advancing scientific understanding and new engagements for citizens.

Moreover, "*The Commission Recommendation on digitisation and online accessibility and digital preservation of cultural material (2011/711/EU) has helped Member States to develop strategies and improve conditions for the entire digitisation lifecycle. Europeana, Europe's digital platform for cultural heritage, embodies the continuous effort of the European Commission and the Members States to democratise access to cultural heritage, foster pan-European collaboration between heritage institutions, and promote interoperability and open access, while respecting copyright*"[18].

The direction traced through the development of the platform will be therefore further strengthened. A common standard, methodologies and guidelines to model data and knowledge aiming at a comprehensive, holistic documentation of European 3D cultural heritage assets; and the definition of framework conditions for an open European repository for storing, managing and re-using interoperable 3D models are indeed among the main EU aims for the coming years.

Notes

[1] Declaration: Cooperation on advancing digitisation of cultural heritage 2019.

[2] Cultural Heritage: Digitisation, online accessibility and digital preservation, 2019.

[3] Cf. Bianchini et al. 2016.

[4] Cf. Iadanza et al. 2019.

[5] Cf. Maietti et al. 2018.

[6] Cf. Balzani, Maietti 2017.

[7] Cf. Di Giulio et al. 2017.

[8] Cf. Maietti et al. 2017.

[9] Cf. Balzani, Maietti 2015.

[10] Cf. Balzani 2016.

[11] Cf. Di Giulio et al. 2014.

[12] Cf. Dore, Murphy 2017.

[13] Cf. Tiano, Martins 2018.

[14] Cf. Bonsma et al. 2016.

[15] Cf. Iadanza et al. 2019.

[16] Cf. Brusaporci et al. 2018.

[17] Cf. Parisi et al. 2019.

[18] Declaration: Cooperation op. cit.

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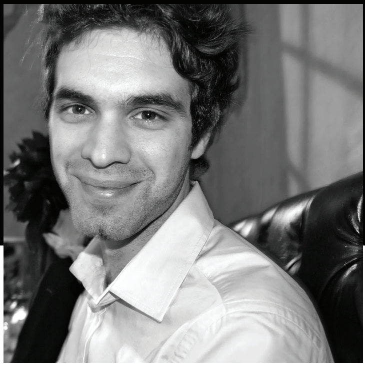


Computer scientist, PhD - focuses his research and development activities on real-time 3D graphics, Virtual Reality, interaction design and 3D user interfaces at the Institute for Heritage Sciences of the National Research Council (CNR ISPC) in Italy. He obtained his Master of Science degree in Computer Science at Bologna University and PhD at Sapienza University (Rome, Italy). He developed several software tools, serious games, online virtual museums, web-applications and web services within national and international projects. He received two Digital Heritage awards for “Best exposition - quality of content” in 2013 (Imago Bononiae) and 2015 (AiRome). He is responsible for different projects dealing with interactive 3D visualization, WebVR/XR applications, interaction models and immersive VR through Head-mounted displays. He is coordinator of one italian unit under DigiLab (E-RIHS infrastructure for Heritage Science).

06 APPLICATIONS OF A COMPACT SESSION ENCODING FOR IMMERSIVE WEBVR ANALYTICS

BRUNO FANINI

Abstract

Within Cultural Heritage, capturing immersive VR sessions performed through HMDs in explorative 3D scenes may provide valuable insights on users' interactions and spatial affordances. Thanks to its recent specifications (WebVR/WebXR) the Web represents an incredible opportunity to create accessible, interactive and usable frameworks for remote VR analysts. Immersive WebVR analytics performed through common web browsers although, raise several challenges, including limited rendering resources, data exchange over the network and encoding/decoding computational workload. Furthermore, unexpected locations of a given 3D scene may receive users' interest: a volumetric approach is required to allow the remote VR analyst to fully understand 3D interactions performed within a virtual environment. This work presents results and applications of a compact, lightweight image-based encoding model designed for remote VR analysts. The integration with existing open-source Front-Ends opens up several possibilities to create fertile ground for interactive and remote VR inspection of immersive sessions. Advantages of the approach are also shown within collaborative VR sessions, and how the analyst can easily extract volumetric attentional synchrony by performing basic 2D image operations.

Nell'ambito dei Beni Culturali, la cattura di sessioni immersive effettuate con visori (HMD) in ambienti virtuali 3D può fornire dati preziosi sulle interazioni degli utenti e sull'importanza percepita di alcuni elementi dello spazio. Grazie alle recenti specifiche introdotte (WebVR/WebXR) il Web rappresenta un'incredibile opportunità per creare framework accessibili, interattivi e usabili per un remoto VR analyst. Le immersive WebVR analytics tramite comuni web browser tuttavia, sollevano diversi problemi, come le risorse di rendering limitate, lo scambio di dati sulla rete e il carico computazionale riservato alla codifica/decodifica del dato stesso. Inoltre, punti inaspettati di un ambiente virtuale 3D possono suscitare interesse nel visitatore: un approccio volumetrico è necessario per permettere all'analista VR la piena comprensione tridimensionale delle interazioni effettuate nello spazio virtuale. Questo lavoro presenta i risultati e le applicazioni di un modello di codifica basato su immagini, compatto e leggero, progettato per l'analisi immersiva remota. L'integrazione del modello con Front-End esistenti open-source, apre molteplici possibilità per creare terreno fertile per ispezionare da remoto sessioni immersive in modo interattivo. I vantaggi vengono mostrati anche in relazione a sessioni VR collaborative, e come un analista può facilmente estrarre attentional synchrony volumetrica eseguendo semplici operazioni su immagini.

Introduction

Within Cultural Heritage and other fields as well, head-mounted displays (HMDs) are often employed in public events or spaces (museums, exhibits, etc.) to offer visitors the possibility to immerse themselves into a 3D virtual environment, although limited by a few constraints (e.g. temporal constraints, visitors serialization, etc.). Recent advancements of WebVR/WebXR API (https://www.w3.org/TR/webxr/) are enabling immersive experiences to be deployed directly on the web, using an HMD and a WebVR browser without any additional plugin or third-party software. Depending on locomotion model adopted for the VR exploration, unexpected elements of the 3D scene may capture users' attention. In this sense, an in-depth investigation of spatial affordances and saliency for a given 3D scene (when perceived through an HMD) can be useful. Furthermore, it can provide valuable data also to improve the overall immersive experience, by prioritizing 3D modeling effort on specific elements. Tracking, recording and visualising the entire history of several VR sessions can thus provide valuable insights on users' behaviour and how they perceive the virtual environment. Furthermore, a remote analyst may need to inspect user sessions while the VR application is running (e.g.: permanent installation, online WebVR application, etc...). Two major challenges to be addressed for immersive WebVR analytics are: (A) large data exchange over the network and (B) a careful management of 3D resources due to rendering limitations of web browsers (including mobile). As remote VR analysts, we need novel approaches to encode and interactively inspect large collected sessions over the web.

Related Work

Because of its inherent openness and accessibility, the Web represent a valid solution to the lack of cross-platform support[1], enabling a "universal" access to immersive VR without requiring additional software. One of the most prominent examples is SketchFab (https://sketchfab.com/), a well-established commercial platform to publish and present 3D content on different devices, including HMDs (immersive VR). WebVR/WebXR API (https://www.w3.org/TR/webxr/) is playing a big role into democratizing immersive VR[2], so more people can experience 3D content through low-cost (e.g. cardboards) or high-end headsets (HTC Vive, Oculus Rift, etc.). It is also fuelling content creators, who need to test and deploy immersive VR scenes on the web, reaching a wide range of viewing platforms.

Image-based encoding can be used to transport spatial information over the web in a compact manner (e.g. coordinates, vectors, etc.) exploiting common 2D images as containers. For instance, Limper and others[3], Dworak and Pietruszka[4], investigated efficient transmission of geometry data over the web using images as data transport. These works also highlighted a few advantages of PNG format[5] that offers a network-friendly, patent-free, lossless compression scheme that is truly cross-platform. Images are also used within networked scenarios to transport quantized scalar values, subsequently decoded by the client GPU: for instance, the Depth Panoramic Frame[6] (and its open-source library[7]) employs PNG images as lightweight transport of depth information for 360 panoramas, restoring original distance on client GPU for a correct 6DOF stereoscopic perception of omnidirectional WebVR experiences.

Capturing, storing, mining and visualising the whole history of all user sessions can provide valuable insights about spatial propensities, users behaviours, saliency and much more for a specific 3D environment. Visual Analytics[8] is a validated approach to perceive patterns and extract knowledge from massive and dynamic datasets, allowing analysts to detect the expected and discover the unexpected. When dealing with long-term interactive 3D installations in fact, large amounts of recorded data related to users' sessions can be collected[9]. Within immersive VR

exploration, locomotion plays a central role[10], thus a deep understanding of users' spatial motions may support or validate the effectiveness of interaction model employed.
There is a growing interest in researching virtual environment saliency for immersive VR, although most of these works focus on 360 or omnidirectional visual content from fixed viewpoints, like[11] for gaze data. Models to obtain fixation locations and maps from head direction were also studied[12], offering a good approximation when eye tracking data is not available. Regarding visual attention analysis, Knorr and others[13] investigated an efficient metric and visualisation method to measure similarity between a director's cut and users scan-paths using color-coded maps.
Immersive Analytics is an emerging research field investigating how new interaction models and display technologies can be employed to support analytical reasoning and decision making[14]. Immersive inspection of multidimensional data represented as 3D scatterplots is also researched in Wagner and others[15], resulting from dimensionality reduction. A few recent works focus their attention on immersive WebVR analytics (immersive analytics using a common web browser) facing the challenges related to online, web-based deployment[16]. They investigated some of the issues faced by developers in creating effective and informative immersive web-based 3D visualisations. The combination of Immersive Analytics with WebVR API is fuelling research in the field of data visualisation, as it offers the remote VR analyst to better perceive patterns difficult to understand using traditional techniques[17].

A compact encoding for VR sessions

A user state can be defined as a collection of state attributes evolving over time (the immersive VR session): for instance, sp (HMD location inside the 3D space), sd (HMD view direction), sf (HMD focal point), and so on.

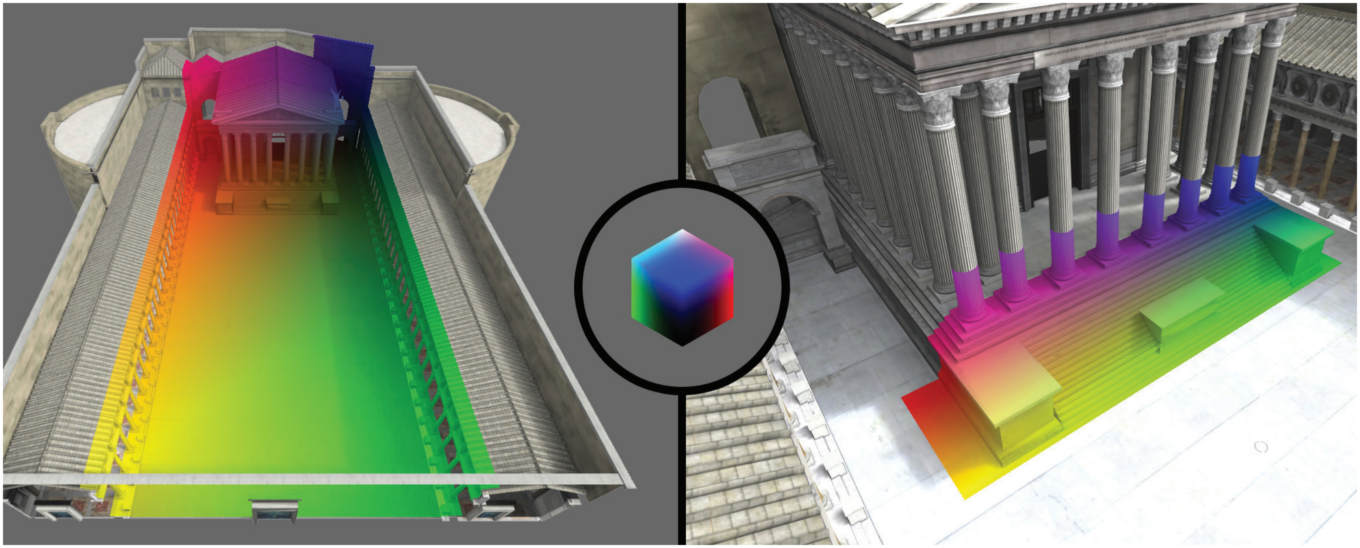


Fig. 1 - Two session volumes with different extents arranged in a roman forum 3D scene, visible geometry is color-coded for clarity

Each casual visitor performs different interactions within a limited amount of time during the public exhibit or during an online WebVR session, dynamically modifying these attributes.
Session volumes[18] are accessories deployed at runtime to observe a volumetric portion of the 3D space, capturing immersive VR sessions. The role of a single volume arranged in a virtual 3D scene is to capture user states within its extents and record them as colour signals: the model allows to encode them as stream of RGB(A) values and aggregate them as common 2D images. In order to encode spatial attributes (e.g.: HMD position, focal point, etc.), a direct mapping between a 3D position and an RGB value is introduced, allowing to color-code each location inside the volume. Each 3D location inside the volume can be normalized (each coordinate ranging between 0.0 and 1.0) and mapped to an RGB colour.
Since the bit-depth of common image formats is limited (e.g.: lossless PNG format has usually bit-depth = 8 per channel) the 3D locations are quantized into a uniform 3D grid of voxels. For instance, using a common bit-depth of 8, the volume is virtually subdivided into 2563 (16.777.216) different voxels. The extents and image bit-depth have obviously a huge impact on the accuracy of recorded 3D locations (the quantization in fact, introduces an error).
The advantage of such approach is to observe limited spatial extents with the goal of capturing and encoding specific user behaviours in standard 2D images. The model allows to arrange and deploy several volumes in the same 3D scene, each observing different extents and encoding user VR sessions, providing great scalability and customization.

Time-driven layout

Regarding a given spatial attribute (e.g.: HMD location) a single VR session (a single user) within a volume can be thus represented as 1-dimensional stream of RGB values. We basically write the entire history of a given spatial attribute as RGB signal, evolving during the session. With this approach, given a fixed temporal step increment (e.g.: 0.1s) each pixel of the signal encodes a specific 3D location. Notice that in order to decode the original 3D coordinates, the client application needs the volume position and extents.
At this point, multiple session signals can be vertically stacked into a 2D atlas called "Quantized Session Atlas" (QSA), with each row of the image representing a specific user (user ID). This means a single 2D image encodes multiple VR sessions with respect to a given attribute (e.g.: user location in the 3D scene). Such atlas layout allows interactive manipulation on GPU as texture data (desktop and mobile Web3D) and offline 2D image processing, providing direct and flexible intervention to visual analysts.

Saliency-driven layout

Spatial attributes (user location, 3D focus, VR controller location, etc.) recorded over time, can be exploited to compute a list of salient voxels (3D locations) in a given volume, providing valuable intel on users' spatial interactions. Depending on persistence over time in a specific location and other contributing factor[19], elements of the 3D scene may exhibit unexpected interest when perceived through a head-mounted display. Massive datasets collected from long-term exhibits or running WebVR applications online can offer a good and valuable estimate of user behaviours and scene saliency. Once we

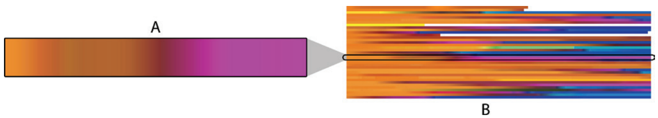


Fig. 2 - (A) single user session represented as stream of RGB values over time; (B) Session Atlas storing multiple sessions encoded as a single image

defined a policy to rank a given voxel, representing a 3D location (e.g. depending on persistence over time) we can sort them starting from the most salient values and encode them as a 1 x k image also called saliency signature.
We use the same mapping method described in the previous section to encode the 3D location into an RGB value, while using alpha channel to encode rank. The sorted layout allows to partially evaluate the saliency signature directly on the GPU by discarding rightmost values (lower rank). For instance, the leftmost pixel maps the most ranked voxel: we can evaluate a well-defined range (usually starting from the leftmost pixel) and progressively compute corresponding 3D locations.

Remote WebVR inspection

The compactness of encoded atlases and signatures was specifically designed to support remote, online inspection by WebVR analysts. The lightweight encoding in fact, already resulted in minimal data size and computational resources needed to encode/decode immersive VR sessions[20]. A dedicated web component has been developed and integrated with the existing open-source CNR ITABC project "ATON" [21] - enabling remote WebVR analytics right inside a browser. The component offers full integration with recent WebVR API to inspect the 3D scene and interact with encoded data through VR controllers. For instance, it is possible for the analyst to interactively move through the timeline of recorded sessions, isolating a specific user or a set of users. It is also possible to inspect saliency signatures, by progressively decode 3D locations to highlight users' interest, or visually analyse relevant locations regarding users locomotion data. The recent integration of ATON with node.js[22] and socket.io[23], allowed also to introduce collaborative WebVR functionalities ("VRoadcast" module) where two or more users remotely located, interact together and see each other in the same virtual environment using HMDs and a WebVR-enabled browser (Mozilla Firefox, Supermedium[24], etc.).

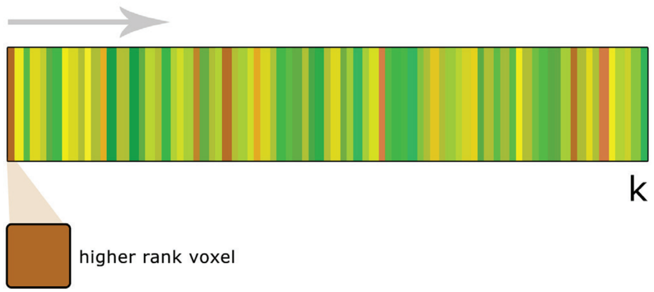


Fig. 3 - The saliency image (center) obtained from casual visitors, from top-left to bottom-right progressively evaluated to identify salient locations of all recorded locomotion data overlaid to original 3D scene

Results

In order to compare the size of image-encoded atlases (QSA) with other formats, the encoding model was initially applied to existing locomotion data, collected by "ovrWalker" application[25] during "TourismA 2018" event and stored as ASCII CSV files. Previous results obtained by the three different scenes on display led to huge compression ratios using QSA with lossless PNG format (around 14%) compared to raw binary format using the same accuracy (three bytes per 3D location). Such huge difference in size using PNG is explained by the time-driven layout of QSA that facilitates compression: RGB data is in fact more likely continuous between neighbouring pixels[26]. On the other hand, obtained saliency signature (locomotion) from the dataset was useful to support prioritization of 3D modeling effort on selective elements of one scene, the "Augustus Forum" (used in Keys2Rome project[27]). These results were specifically useful during the assets creation pipeline for the new applied VR game developed in REVEAL[28] project.
In order to investigate more in detail remote WebVR inspection over the network, a new experiment was carried

out with a small group of users (10 participants) on a sample 3D scene, each exploring the environment while wearing an Oculus Rift HMD. Lossless PNG format (bit-depth = 8) was employed for all encoded image atlases. A common teleport-based locomotion model[29] was adopted (similar to the one used by SketchFab platform) using HMD view direction to pick a teleport location on the surface (in this case, the floor).
Thanks to the compact encoding, the QSA for the locomotion of all VR sessions resulted in 8,89Kb, compared to 30,64Kb of binary format (3 bytes per location, same accuracy) and 570,1Kb of original CSV data (ASCII). Focus QSA (encoding attention over time for all users) resulted in 16,7Kb: the larger size (almost double) compared to locomotion QSA is due to the frequent, fine-grained variations of users focus on 3D geometries, while locomotion data had slower changes over time due to the teleport-based model. Regarding saliency signatures, experiment reports a focus signature of 3,37Kb and locomotion signature of 3,18Kb, both holding 1024 different salient 3D locations (voxels) computed by all sessions.
A WebVR analyst remotely located inspected the ongoing

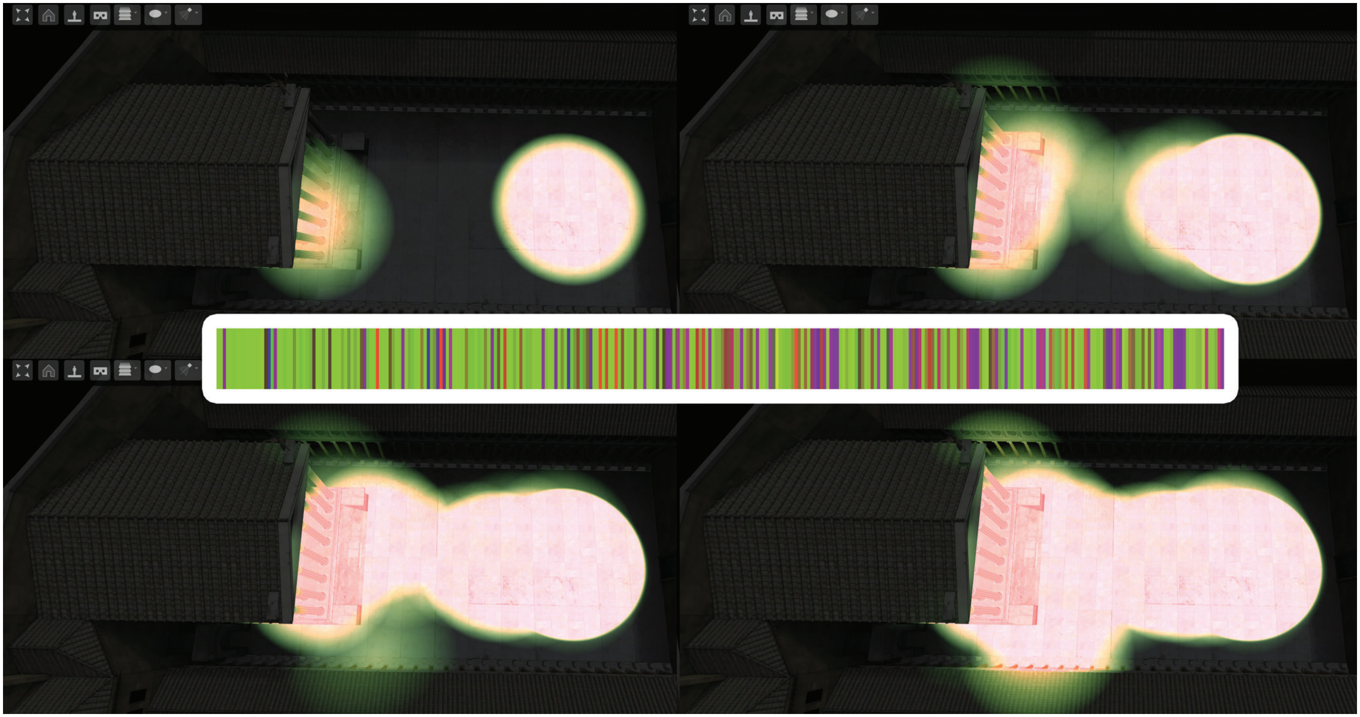
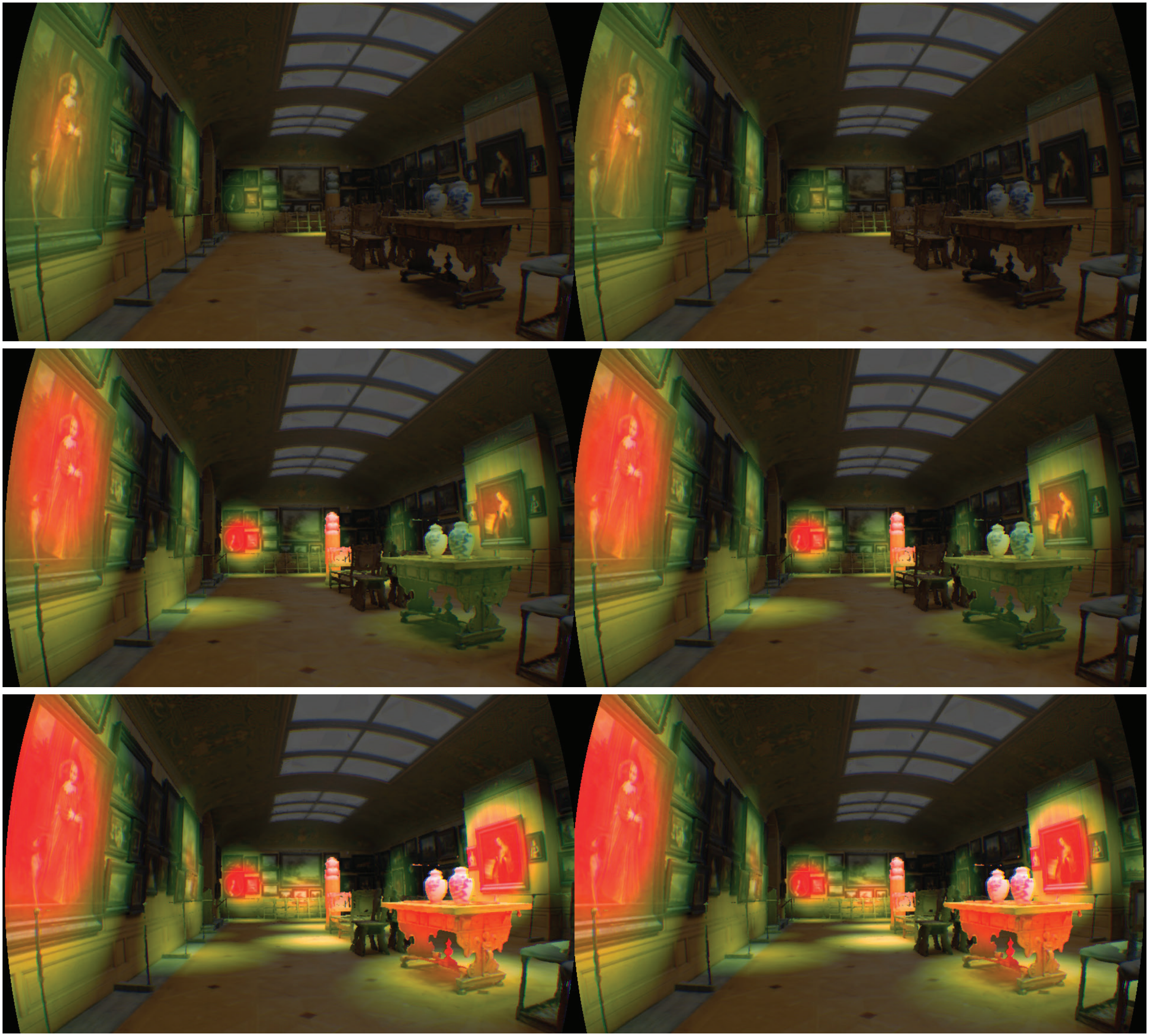


Fig. 4 - The saliency image (center) obtained from casual visitors, from top-left to bottom-right progressively evaluated to identify salient locations of all recorded locomotion data overlaid to original 3D scene

Fig. 5 - Analyst WebVR interface to interactively evaluate salient focus locations, using VR controllers



recorded sessions, interactively analysing the progressive spatial interest mapped on the same 3D scene. This allowed him to easily identify elements that captured users' interest and highlight salient areas where participants used to stop (specifically to observe room details, paintings, etc.). Salient focus locations also did highlight how the locomotion model adopted impacted neck motions: users frequently focused on floor in order to pick the next location to teleport.
The collaborative module also allowed to carry out a second experiment with two HMD users in the 3D scene at the same time (exploring the room together synchronously, seeing each other). The encoding layout of QSA in this case offered a simple method to compare volumetric attention during the session on the same locations, also called in literature attentional synchrony[30]. Thanks to the QSA layout in fact, it is possible to directly compare two (or more) RGB signals and perform basic image subtraction operations. In this specific case, the colour difference/distance (inverted and then normalized) allows to highlight attentional synchrony over time during the collaborative session.

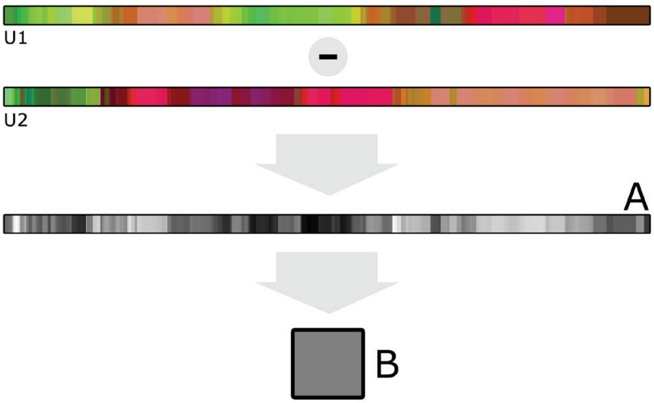


Fig. 6 - Focus QSAs of two collaborative sessions (U1 and U2) synchronously exploring the 3D scene. Basic color difference/distance operations can be employed to compute attentional synchrony (A) and the weighted average between the two users (B)

It is also possible to employ other basic 2D image operations like average to extract the average attentional synchrony between the two users U1 and U2 for the duration of the session.

Conclusion

This work presents some applications of an image-based encoding model designed to capture immersive VR sessions volumetrically. When directly mapped to the original 3D scene, recorded data offers easier interpretation for spatial analysis and usable 3D visualisation. Users' HMD interactions are recorded inside specific session volumes and encoded in compact, lightweight PNG images that allow comfortable transport to remote WebVR analysts. Several session volumes can be arranged and deployed at runtime in different locations of the same virtual environment for more selective analyses. Proposed methods can be exploited for direct, interactive manipulation of captured data on GPU hardware and through offline 2D image processing. Sample experiments are described, reporting data size compared to other formats, including time-driven layouts (encoding the entire VR session) and saliency signatures (relevant elements of the 3D scene). A collaborative experiment is reported and how basic image operations can be employed to extract attentional synchrony between two users exploring the 3D scene at the same time. There are already several applications for the encoding model that are under investigation, including for instance real walking (encoding physical HMD motions in large tracked areas as images) and handheld devices such as VR controllers. Described encoding methods can be replicated with ease using other 3D libraries and devices, ranging from desktop VR to mobile browsers. Results of this research and developed web components were integrated with new release of "ATON" project, and they will be open sourced for other researchers willing to re-use the model in other projects.

Acknowledgements

Special thanks to Hallwyl Museum and their 3D models freely available (CC BY-SA 4.0) on SketchFab; D. Ferdani (CNR ITABC) for samples of 3D models used for Keys2Rome project (http://keys2rome.eu/)

Notes

[1] Cf. Dibbern 2018.

[2] Cf. MacIntyre, Smith 2018.

[3] Cf. Limper et al. 2013.

[4] Cf. Dworak and Pietruska 2015.

[5] Cf. Wiggins et al. 2001.

[6] Cf. Fanini, d'Annibale 2016.

[7] http://osiris.itabc.cnr.it/scenebaker/index.php/projects/dpf/

[8] Cf. Wong, Thomas 2004.

[9] Cf. Agus et al. 2016.

[10] Cf. Boletsis 2017.

[11] Cf. Sitzmann et al. 2018.

[12] Cf. Upenik, Ebrahimi 2017.

[13] Cf. Knorr et al. 2018.

[14] Cf. Marriott et al. 2018.

[15] Cf. Wagner et al. 2018.

[16] Cf. Butcher, Nigel, Ritsos 2019; Butcher, Roberts, Ritsos 2016.

[17] Cf. Hayet et al. 2018.

[18] Cf. Fanini, Cinque 2018.

[19] Cf. Agus et al. 2016.

[20] Cf. Fanini, Cinque 2018.

[21] http://osiris.itabc.cnr.it/scenebaker/index.php/projects/aton/; Cf. Fanini, Pescarin, Palombini 2019; Barsanti et al. 2018.

[22] https://nodejs.org/en/

[23] https://socket.io/

[24] https://www.supermedium.com/

[25] http://osiris.itabc.cnr.it/scenebaker/index.php/projects/osglab/ovrwalker/

[26] Cf. Limper et al. 2013.

[27] http://keys2rome.eu/. See Pescarin 2014, Fanini et al. 2015, Pagano, Armone and De Sanctis 2015

[28] https://revealvr.eu/

[29] Cf. Boletsis 2017.

[30] Cf. Smith, Henderson 2008.

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07 AI: ARCHITECTURAL INTELLIGENCE. DEEP LEARNING AND HERITAGE ENVIRONMENTS

VALERIO PALMA

Abstract

An unprecedented computing power and the vast datasets recently available have boosted machine learning techniques, featuring algorithms that can "learn" from experience. These are gaining importance in many disciplinary fields, dealing with computer vision and object recognition problems. Nevertheless, the applications of such tools in the fields of architecture and cultural heritage are still limited, as well as the spread of public datasets to encourage experiments and research.
This contribution presents a project on artificial intelligence (AI) technologies aimed to support the management and accessibility of both architectural heritage and the connected multimedia information. Original developments of a deep learning model based on convolutional neural networks are employed in a smartphone app to recognize monuments framed using the camera. AI recognition works from different viewpoints and does not need any reference image stored on the device. Once the monument is identified, the app provides the user with information previously downloaded from the web. The Central Archaeological Area in Rome has been a test field for the first experiments.
The app prototype shows that AI offers a chance to enhance existing digital archives and deal with open issues in managing spatial information.

Grazie a potenze di calcolo senza precedenti e alla disponibilità di vasti dataset, le tecniche di machine learning, che prevedono algoritmi capaci di "imparare" dall'esperienza, sono applicate a problemi di computer vision e riconoscimento di oggetti in molti ambiti disciplinari. Tuttavia, l'uso di questi strumenti nel campo dell'architettura e dei beni culturali è ancora limitato, così come la diffusione di dataset pubblici per stimolare ricerca ed esperimenti.
Il contributo presenta un progetto che studia le tecnologie dell'intelligenza artificiale (AI) per supportare la gestione e l'accessibilità del patrimonio architettonico e delle informazioni multimediali connesse. Un modello originale di deep learning, basato su convolutional neural networks, è impiegato nello sviluppo di un'applicazione per smartphone capace di riconoscere i monumenti inquadrati attraverso la telecamera. Il riconoscimento tramite AI può funzionare da diversi punti di osservazione e senza la necessità di immagini di riferimento memorizzate sul dispositivo. Una volta individuato il monumento, l'app rende disponibili all'utente le informazioni precedentemente scaricate da una piattaforma web. Il primo esperimento completato ha riguardato i monumenti dell'Area Archeologica Centrale di Roma.
Il prototipo mette in luce come l'AI offra opportunità per valorizzare gli archivi digitali esistenti e dare nuovi contributi ai problemi aperti sulla gestione dell'informazione spazializzata.

Accessing space, accessing information

The digital world is permeating and altering the readings of the city and the experience of architectural heritage. Constantly evolving tools are nurturing information gathering, and datasets are growing in size, detail and complexity. However, care must be taken not to mistake the sprawl of analytical layers and the amount of data with the understanding of heritage and the capacity to manage it and plan its role in the contemporary city. Information and communication technologies (ICTs) can help to trace clear paths through digital environments and facilitate access to documents and data, but landmarks are needed to navigate across information and organize a growing knowledge.
The present contribution introduces a project on the use and accessibility of cultural heritage (CH) sites, the targeted employment of ICTs and the effective management of information on the built space. The project is carried out at the Future *Urban Legacy* Lab[1] (F*U*L*L*) of Politecnico di Torino, as part of a research stream on heritage technologies.
As a first challenge, we address the lack of proportion between the cultural role played by architectural heritage and the resources allocated. Italy has 49 cultural sites on the UNESCO World Heritage Sites list. Despite this, only the 0.7% of Italian GDP is allocated to culture[2]. Sites such as the Imperial Fora in Rome or Pompeii and Herculaneum host millions of visitors each year but can't provide appropriate informative services on site, and face management and maintenance problems. At the same time, due to low tourist flows, many small, isolated or less known historical and archaeological sites cannot afford surveillance and maintenance, and thus are not accessible. We need to optimize the available resources in order to guarantee the protection of cultural heritage and enhance its value.
Another challenge is to manage the new kind of information the technology is making available. Thanks to an unprecedented development of the tools, the city is now producing brand new information about itself. We have to continuously redefine the networks of relationships between documents and data, according to updating needs and contents.
Under the hypothesis that the physical form of the built environment plays a key role in the construction of new data models, tools like those of digital survey, spatial information modelling, augmented reality (AR) and artificial intelligence (AI) can synergistically work together to improve our knowledge of the strata that make up the city, and their interaction. These techniques do not have clear boundaries and many overlaps and interactions are possible, especially through the fast development they are experiencing.
We have begun to study these connections from AI, as a means to make data networks and digital environments accessible from the physical space. On the one hand, we try to imagine a platform to get in contact with a digital archive of texts, models and images on architectural heritage. On the other hand, we aim to enable easy search for information, a stronger link between data and localization, interactions with documents for different users and different purposes.
Of course, many tools already connect single artworks to related information. Nevertheless, solutions such as audio tours and QR codes require site-specific design and a physical infrastructure, which can be easily perishable and not compatible with complex information flows.
We think that mobile computing technologies can overcome the limitations of such traditional media and allow novel interactions with monuments and works of art. An inspiring and worth to note fact is that widespread devices like our smartphones can already connect large databases and a direct experience of the city. We just ask, and a *smart* voice assistant listens to music, recognizes it and connects us with further information and services.
What if we could ask "*hey phone, what am I looking at?*". The idea is to frame a monument with the camera

Fig. 1 - Temple of Saturn and Temple of Vespasian and Titus in the Central Archaeological Area, Rome. Credits: Sarah Nichols (CC BY-SA 2.0).

and get access to a data network that is linked with that architectural object, its position in the city and its spatial characteristics.

As a first experiment, we produced a prototype mobile app for the Archaeological Central Area in Rome, which includes the Imperial Fora. Here, a practical need arises: providing an appropriate, precise and complete informative service — for different kinds of visitor, different languages, different levels of detail — with limited impacts on the site and its maintenance.

We pursued the development of a lightweight app to be used offline, thus making it suitable for a large number of users and many sites, even where wireless connectivity is not available.

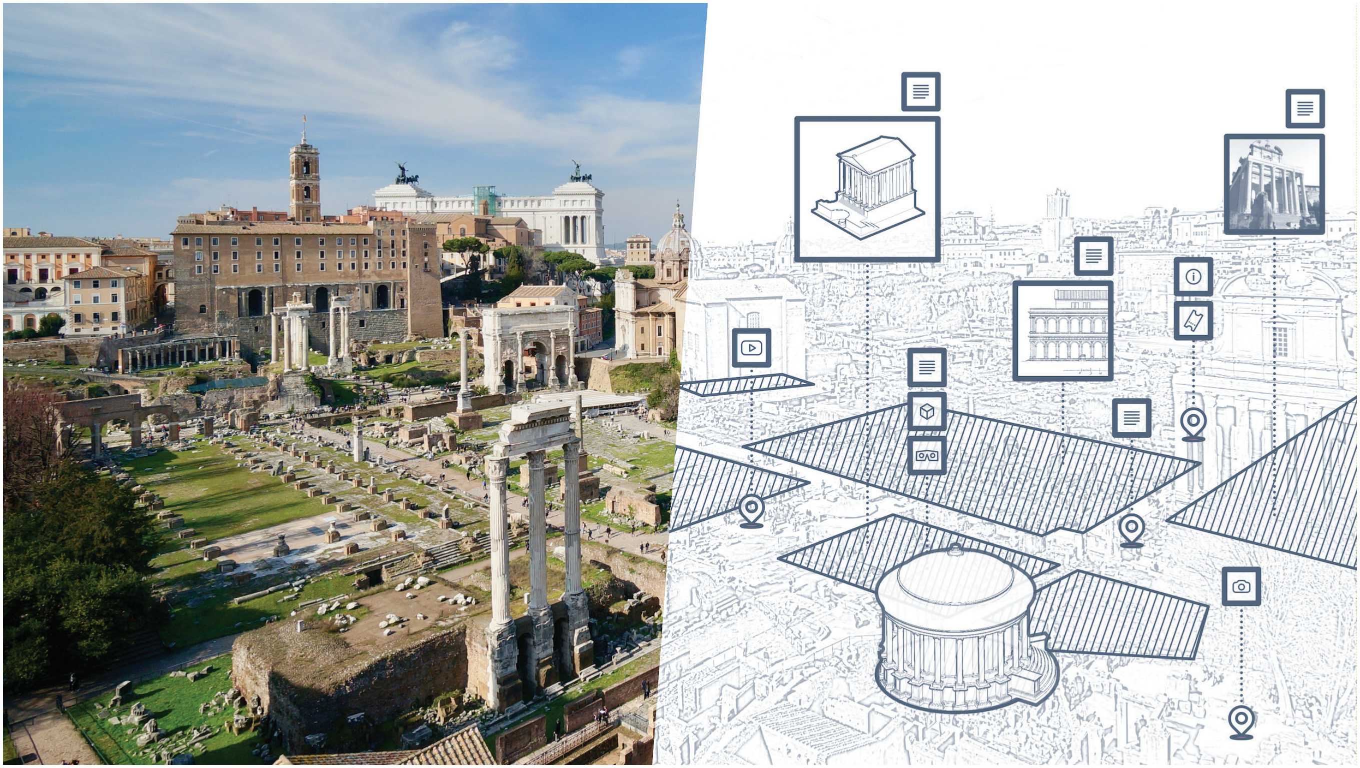

Fig. 2 - The project envisions the space of heritage sites as an access level to digital environments.
Credits: Future Urban Legacy Lab, Politecnico di Torino.
Original image: Andrew and Annemarie (CC BY-SA 4.0).

AI, heritage and spatial models

Thanks to the unprecedented computing power available, AI is now experiencing a very fast development. Deep learning (DL) is a subset of machine learning (ML) algorithms that has substantially improved the capacity of a machine to represent and interpret data[3]. These models, based on techniques dating back to the 1940s, were developed since the 1980s and are now exploiting the advantages of large-scale datasets and GPU computing, gaining a great industrial interest. DL algorithms can "learn" from experience and are capable to deal with "*complicated concepts by building them out of simpler ones*"[4].
Convolutional neural networks (CNNs) are popular and efficient DL models which have specialized architectures for computer vision, outperforming previously used algorithms and finding applications in many research fields[5].

Recent applications of CNNs to architectural issues include building façade segmentation[6], object detection and segmentation in street-level imagery[7] and architectural landmark classification[8]. However, much attention has still to be paid on finding an optimal model to classify architectural objects and features, and specific datasets for architecture- and heritage-oriented ML development still seem to be missing.

Since many works on the digitalisation of cultural sites and related archives have been conducted[9], the heritage field offers structured and ready-to-use sources of knowledge that can enable experiments and be explored through AI techniques. Spatial information modelling tools have a preeminent role in such digital archives. Enabling a connection between geospatial representations and attributes stored in a database, geographic information systems (GIS) have extensively been exploited in CH research[10]. In the last two decades, the spatial management of architectural information has been deeply connected to the building information modelling (BIM) technologies, which allow complex 3D parametric representations. BIM has been applied to existing buildings[11] and specific methods for historic structures and related databases have been developed (historic BIM, or HBIM)[12].

As appears from reviews and attempts to integrate the different approaches of GIS and BIM[13], a common issue is how to exchange information between models based on different standards and semantics. Research on how AI classifies and recognizes architecture from spatial features intertwines these topics and can make a contribution to the identification, structuring and operational use of architectural form.

Developing an "intelligent" digital guide

Using image classification techniques based on CNN models[14], we developed a mobile app that connects the real city to a set of documents such as images, texts, 3D

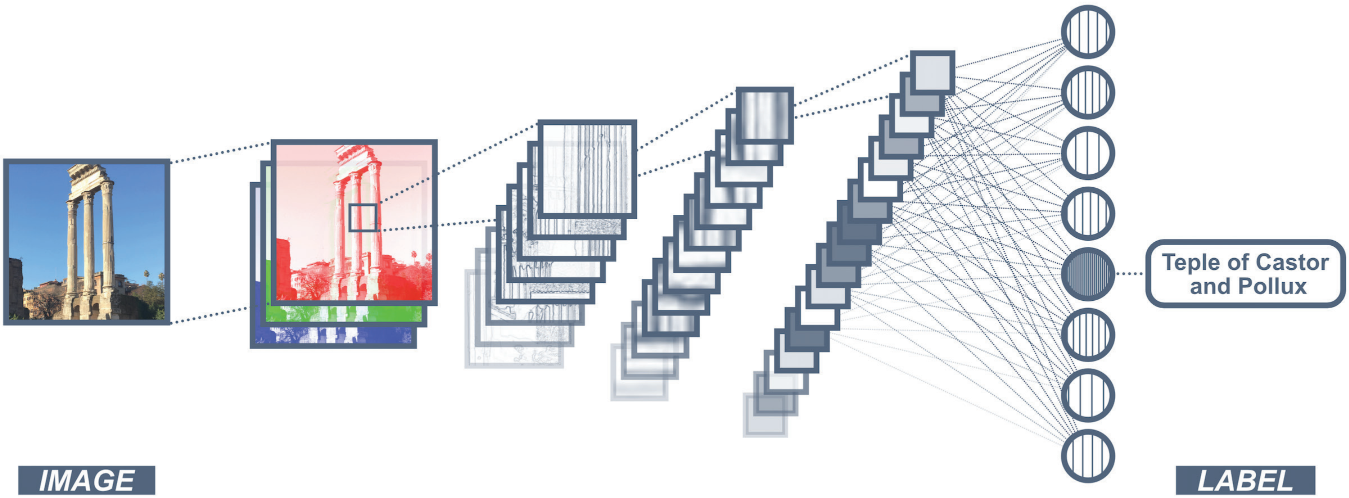

Fig. 3 - Scheme of a convolutional neural network applied to image recognition. Credits: Future Urban Legacy Lab, Politecnico di Torino.

models. It allows users to access a spatial database just by pointing the camera at a monument. We propose a shift from user geo-localization to the localization — both in the physical space and in the network of its related data — of what a user is looking at.
The app is composed of two main blocks of software: (1) an online, geographic-enabled database that makes it possible to upload different types of document and the related information and metadata; (2) the DL part, which is stored on the device and requires a very small amount of disk space. Up-to-date information can be downloaded from the web when the device is connected. When the recognition process is performed, the app gets an identification label from the AI algorithm and sends a query to the local database to fetch data.
The DL algorithm that processes images to get labels is made of interconnected functions called neurons (originally inspired by biological neuron behaviour). Each neuron receives values from other neurons and computes a weighted sum of the inputs to produce an output value. A first set (or layer) of neurons gets inputs from the pixel values of the input image and further layers extract

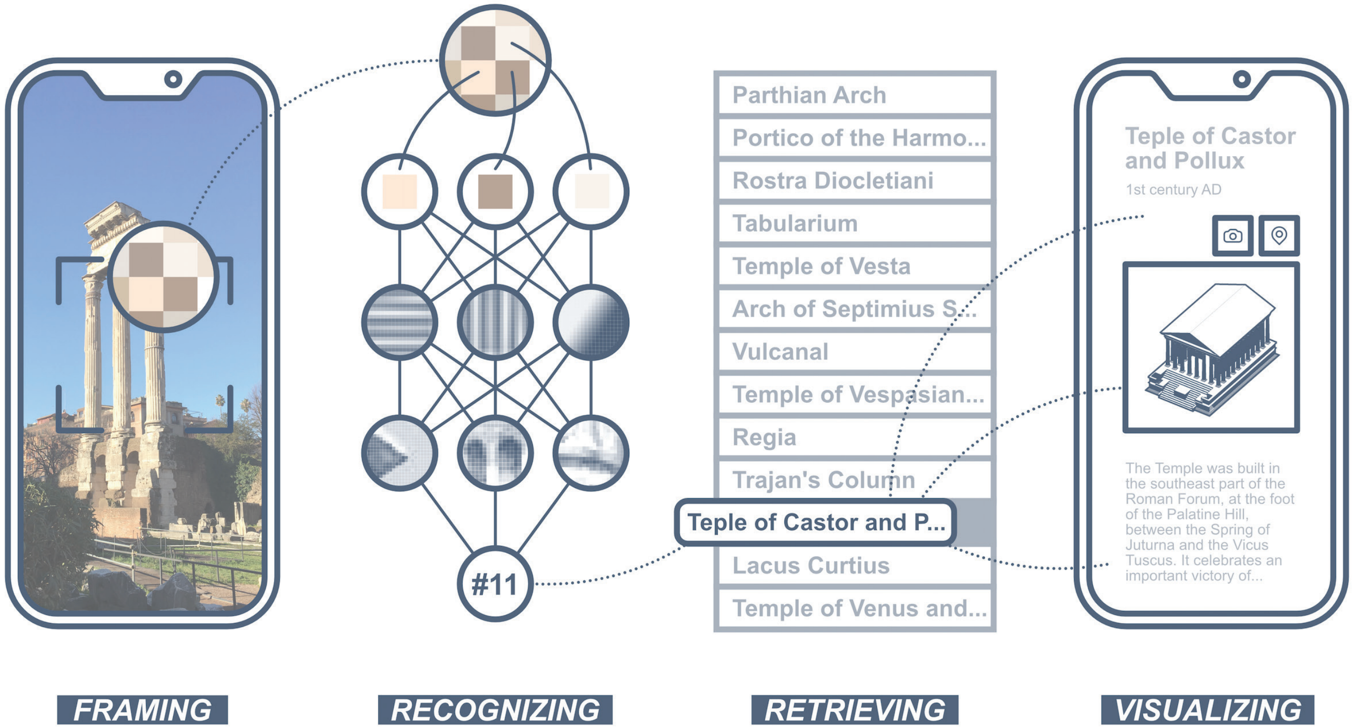

Fig.4 - Scheme of the developed app. The software uses deep learning to recognize monuments, then it retrieves and shows detail information. Credits: Future Urban Legacy Lab, Politecnico di Torino.

Fig.5 - The app features two main views. The first one lets the user frame monuments through the device camera. The second one shows data such as texts, images and navigable 3D models. Credits: Future Urban Legacy Lab, Politecnico di Torino.

increasingly abstract features, by comparing previous layers. These groups of neurons detect edges, then corners, contours and object parts, and finally recognize the object. Among the software tools, the open source libraries Keras and Tensor Flow were chosen to code the neural network. A second set of free and open source tools was employed to set up the web archive. The archive is stored on servers at the Università di Padova and it is accessible on the Cult website (Cult project 2018). The Swift programming language and the Core ML library were used within the Xcode environment to develop the prototype app for the iOS systems.
The app consists of two main user interface views and it was built aiming at ease and speed of use. A first view lets the user frame a monument using the camera. Automatic recognition algorithms compute predictions and, once accuracy exceeds a pre-determined threshold, the app shows the resulting monument title. When an object is recognized, the user can access monument details just by touching the camera frame on the screen. The second view shows data and documents such as texts, images and navigable 3D models.
The AI "learns" to recognize images through a training process, during which the machine optimizes a set of internal parameters, called weights, in order to make its prediction closer to the correct answers for a dataset of manually labelled images[15].
We built a training dataset covering 46 Roman monuments. Pictures were expressly taken for the project, aiming to give a complete overview of the architectural characteristics of the selected objects. Specific attention was given to the most common views for a visitor, including details, panoramic views and different lighting conditions. Some issues were related to the heterogeneous dimensions and conservation status of the monuments, these being sometimes quite incomplete, or part of more recent buildings.
Operations such as translation, rotation, scaling, noise injection and colour alterations were performed to multiply the training dataset and make the AI face a wider range of conditions. Such alterations are called *augmentation* techniques, and have proven particularly effective for DL object recognition[16]. The final dataset contained about 500 images per monument.
The training was conducted using a GPU cluster. Although the process was quite time expensive, a model can be re-trained, so new data can update a previously processed training status. The overall accuracy was calculated at 95% using a test subset of the input pictures. In fact, field tests revealed a much more heterogeneous behaviour of the recognition function across different monuments. Large objects such as the Domus Augustana or the Trajan's Market, which present many different parts resulted in objects being often mistaken for these larger ones. In

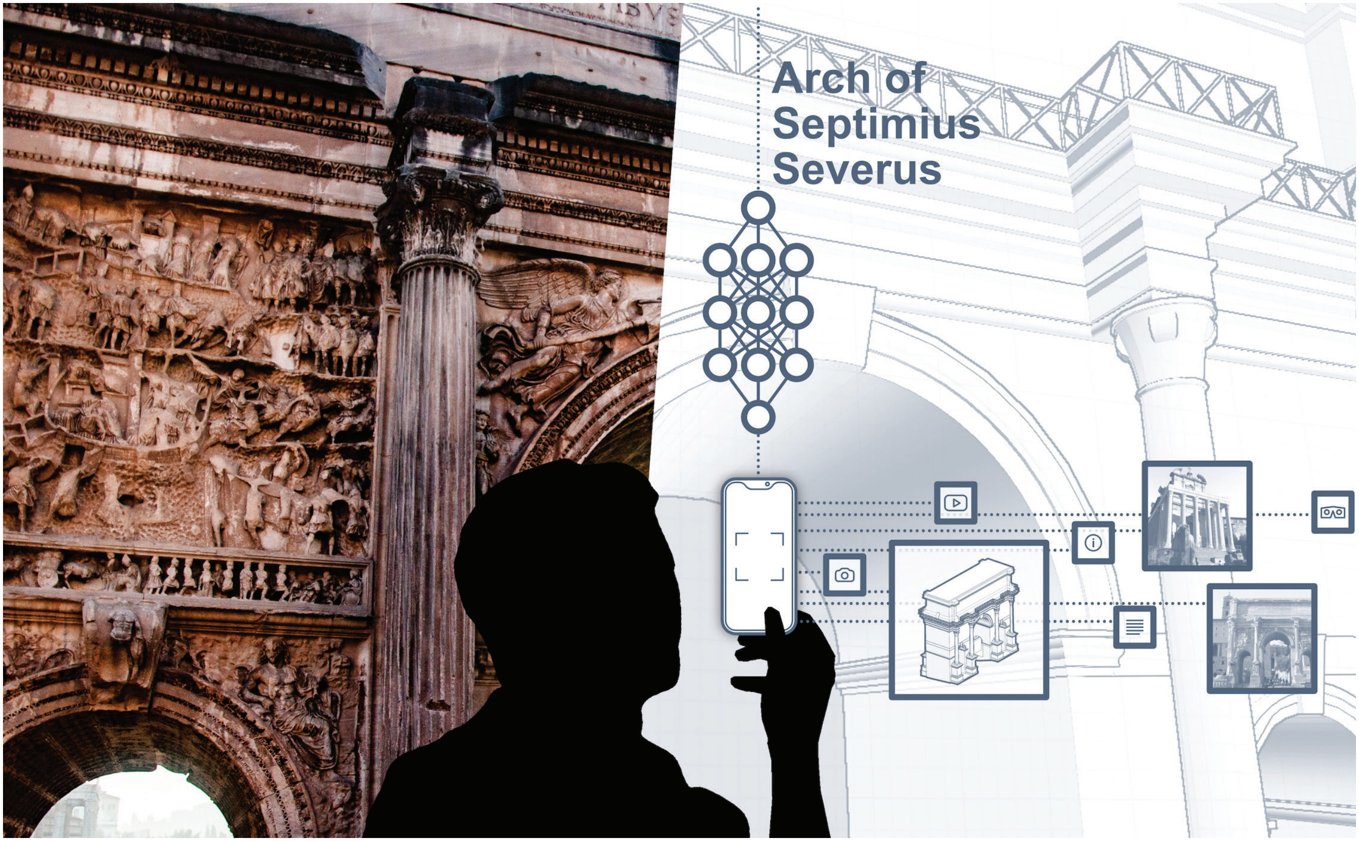

Fig.6 - The app allows users to access a spatial database just by pointing the camera at monument. A shift is proposed from user geo-localization to the localization of what a user is looking at both in the physical space and in the network of its related data.
Credits: Future Urban Legacy Lab, Politecnico di Torino. Original image: Sarah Nichols (CC BY-SA 4.0).

the final model, these monuments were divided in sub-elements, each one with its own label.
The resulting AI "brain" is a lightweight model of just 13 MB. We expect this kind of model to learn to recognize a much larger number of objects, without significantly changing size, which is constrained by the neural network size.

What's next

The app is an access point to a yet under-exploited network of digital information. Instead of being found in a catalogue or a map, a large amount of multimedia content can be linked to the physical elements of cultural sites, answering questions on how to make newly available

information easily and sustainably reachable.
Future developments can of course expand the information connected to the app. The Central Archaeological Area in Rome is the first test field of the developed "AI guide", but this is just one among the possible applications of this technology. CNNs are general models and can be trained to recognize a wide range of objects. We are planning to extend the project to other sites, covering different scales and time spans.
Furthermore, we are working on how to bridge our AI experiments to other technologies: AR can improve the interaction with 3D digital models and superimpose digital information layers on live images of the real environment; 5G cellular mobile communications can make large amounts of data immediately available, redefining location-based services and content access; IoT devices can enable remote access control and enhance on-site experience, providing cost-effective monitoring solutions which do not need the physical presence of supervising personnel.
While AI is just beginning to interact with the built environment, heritage technologies have long been producing and exploring digital models and spatial archives. The interaction between DL algorithms and information modelling, with its underlying semantics, should lead the way to both exploit heritage collections and optimize new object recognition techniques. In fact, one of the main challenges remains to build DL tools which are specific for architectural heritage. Models could be trained to recognize building types, construction techniques, structural components, materials, decorative styles and relations between the parts.
As many have pointed out, the availability of vast and public datasets has been a boost for the development of DL models. Nevertheless the "*drosophila*" of architectural machine leaning[17] has still to be found.

Notes

[1] *FULL* is an interdepartmental research center at the Politecnico di Torino. The project is part of *FULL's HeriTech* research stream. The team working on the project is composed by Matteo Robiglio (full professor in Architectural and Urban Design), Francesca Frassoldati (associate professor in Architectural and Urban Design), Claudio Casetti (associate professor in Communication Engineering), Louis N. Andrianaivo (research fellow) and the author. The author is working on the project as a PhD candidate in *Architecture. History and Project* at the department of Architecture and Design of the Politecnico di Torino. Louis N. Andrianaivo first worked at the ML model as a PhD student at the Department of Mathematics of the Università di Roma Tre. The ReLOAD_Research Lab of ArchitectURban Design of the Università di Padova has made available and maintained the Cult web service (Cult project, 2018). The project is carried out in partnership with Roberto D'Autilia.

[2] Source: Eurostat, General government total expenditure on 'recreation, culture and religion', 2015. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20170807-1 (accessed on 26 March 2019)

[3] Cf. Hosny et al. 2018.

[4] Cit. Goodfellow et al. 2016, p. 1.

[5] Cf. Hosny et al. 2018; Webb 2018; Amato et al. 2016.

[6] Cf. tathopoulou, Remondino 2019.

[7] Cf. Cordts et al. 2016.

[8] Cf. Gada et al. 2018; Amato et al. 2016.

[9] Cf. Cecchini et al. 2018; Haus 2016.

[10] Cf. Soler et al. 2017; Cerutti et al. 2015; Apollonio et al. 2012.

[11] Cf. Volk et al. 2014.

[12] Cf. Murphy et al. 2009.

[13] Cf. Liu et al. 2017; Saygi and Remondino 2013.

[14] A variant of MobileNet V1 models is used; Howard et al. 2017.

[15] Cf. LeCun et al. 2015.

[16] Cf. Goodfellow et al. 2016.

[17] Geoffrey Hinton has defined the MNIST dataset, collecting handwritten digits and related labels, *"the drosophila of machine learning"*, to stress its importance in ML research. Ibid., p. 22

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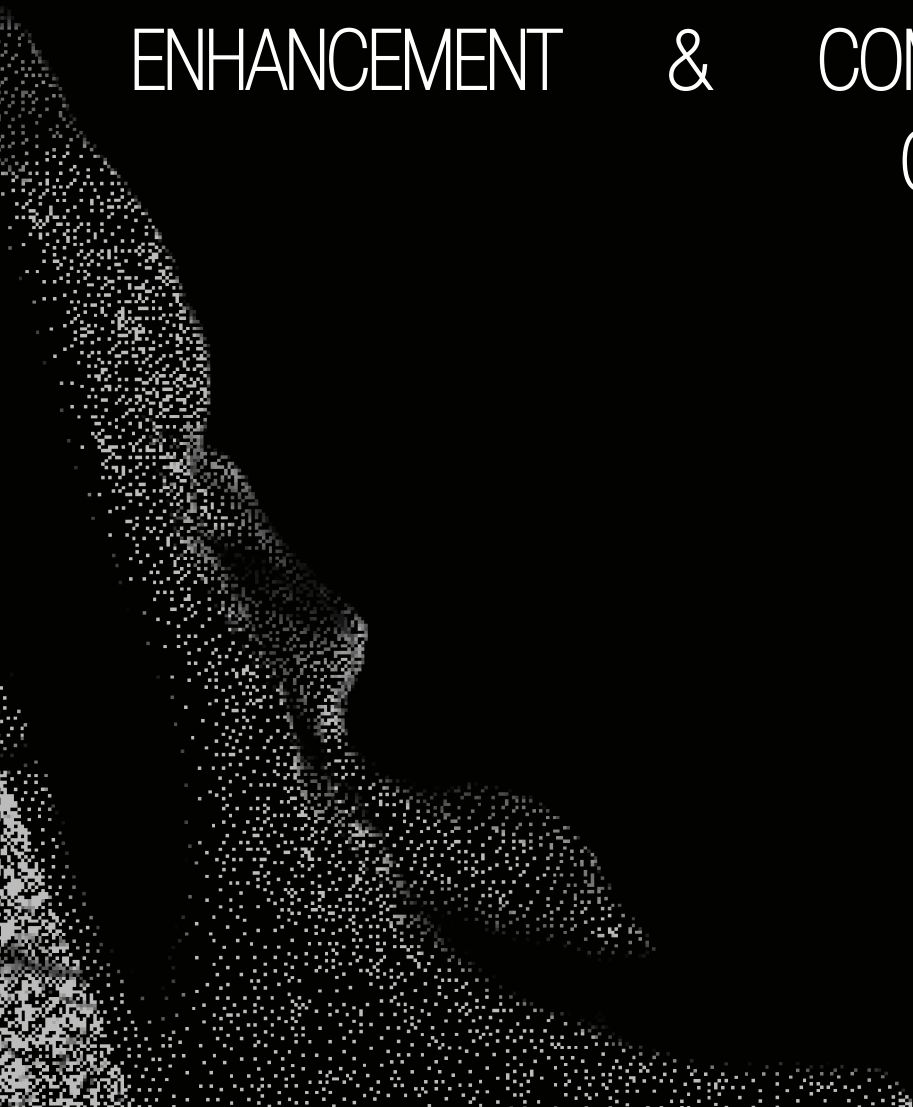
PART III

DIGITAL REPRESENTATION FOR KNOWLEDGE, ENHANCEMENT & COMMUNICATION OF CULTURAL HERITAGE



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His research activities (divided into theoretical, design, implementation and testing of experimental models) are focused on the application of new digital technologies to the disciplines of the survey, drawing and visual communication, with the aim of anticipating future operating scenarios and solve contemporary application problems.
Subject of special study, which crosses all his research, is the definition and representation of an integrated and dynamic model that consists by heterogeneous information. The most recent essays focus on issues of interactive virtual representation, rendering, digital and physical modelling. He teaches at the Faculty of Architecture of University of Rome "La Sapienza", in the degree courses in architecture and industrial design.

THE SCIENTIFIC AND CULTURAL IMPACT OF DOCUMENTATION

Cettina Santagati, Graziano Mario Valenti

The fundamental basis of all science is the theoretical apparatus. Documentation, i.e. knowledge management, being the subject of ever-increasing theoretical contributions, has now consolidated its position in the sphere of science. It is difficult, perhaps impossible, to place it within a specific research area, because knowledge management concerns any researcher. It, therefore, appears to be the most multidisciplinary of all sciences.
The theory of science is not born from anything: it is the result of a process of synthesis and abstraction inspired by the experience, produced by observation and experimental practice.
Therefore, in addition to the specifically dedicated research, studies and experiments that have a different main objective but dedicate particular resources to documentation processes are of fundamental importance. In particular, we refer to those researches that have a particular interest in the communication of knowledge, today declined in the ‘primary’ and ‘distinct’ objectives-channels of dissemination and scientific divulgation. When we say ‘primary’ we refer to the fact that they are the driving energy of thought and therefore the stimulus of new knowledge; on the other hand when we say ‘distinct’ we want to specify that the term “disseminate” indicates the processes of peer communication, whilst the term “divulge” has as its objective the generalized spread of knowledge, to a wide and heterogeneous public.
Dealing with dissemination, the quality, completeness, interoperability, and stability of information are the main critical issues of communication because the transmission of knowledge allows building new knowledge.
In the case of divulgation, where the transmission of knowledge is aimed at its simple acquisition, the values to be focused are instead the synthesis, simplicity, and accessibility for all.
In addition to these first mentioned qualities, it is desirable that they are always accompanied by several others, capable of enriching and specializing in the communication scenarios.
Another quality is the availability of information: the data freely available to the scientific community today are still too few compared to the amount produced; similarly, the cultural heritage that can be enjoyed today is only the most emerging part of a considerably larger heritage. While there is a need to refine the legislation on open access and open data in terms of research products and more generally of cultural assets, it is equally appropriate that there should be actions aimed at changing the cultural vision of both individuals and communities; actions aimed at the democratization of science that make it clear that sharing knowledge in the long term makes it worthwhile.
Two other important qualities that should be mentioned together are the accuracy and repeatability of the data acquired and processed into information: any act of documentation should always be accompanied by metadata specifying the level of reliability and the survey methodology used to define it.
Correct and full dissemination provides for the transfer

of data and methodologies so that - among peers - it is possible to repeat the same investigative activity and confirm, refine or refute it.
The integrability of the data, perhaps today better expressed by the term "interoperability" is the quality that expresses the possibility for different users to analyse and process together heterogeneous sets of information. The integration of information is the main way to exploit digital aid in a congenial way, producing new information from the simple elaboration of the pre-existing ones.
Each of these above-mentioned qualities is in the investigative background of the authors who have contributed to this session dedicated to Theory, and in addition, they are enriched by personal interpretations that show the fertility and liveliness of this field of research.

Donato Maniello in "*Digital anastylosis in augmented digital spaces: Spatial Augmented Reality applied to cultural heritage*", literally immerses us in a careful selection of digital anastylosis highlighting the duplicity of the pervasive and at the same time the persuasive character of the experience. He also suggests how these knowledge-sensitive environments allow a natural hybridization of analog and digital technologies.
The portions restored and reconstructed through digital anastylosis, of an immaterial nature, in these environments assume consistency and configure a sort of "materiality of information".

Andrea Marraffa in "*The material culture of theatre: analysis of liparote theatre masks for the compilation of a digital protocol of integration and anastylosis*" illustrates a complete research experience, which is a real operational protocol suitable and repeatable for the investigated case study. A methodology that originates from the collection and analysis of documents and then passes through the survey, digital modeling and arrives at the physical prototyping of the models, intended as a valuable set of communication.

Leonardo Baglioni and Marta Salvatore in "*Digital models for the analysis and communication of perspective space*", show how an accurate use of digital representation can give new value and revitalize analog representation and open new fields of study and applications. In particular, through parametric modeling of the perspective space, they show how it is possible to dynamically explore projective transformations, reveal their theoretical principles and understand their perceptive implications.

Daniele Rossi, Federico Orfeo Oppedisano and Carlo Vinti in "*Food and wine heritage in the Marche region: digital storytelling through virtual and augmented reality*", present a research project in which a key role is played by the "narrative" integration of data, a set of historical, cultural and artistic information that supports and enriches the communication of a remarkable Italian heritage concerning "Food and wine heritage". Particularly interesting and courageous is the experimentation of unusual VR and AR systems for this kind of documentation.

Four researches, therefore, of considerable innovation and scientific and cultural impact, which can only provide the reader with useful food for thought and innovation.

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08 AN EXTENSIVE ANALYSIS OF THE MAGNO-GREEK TERRACOTTA THEATRICAL MASKS OF LIPARI AND DEVELOPMENT OF A PROTOCOL FOR THEIR (DIGITAL) INTEGRATION AND THEIR (SEMANTIC) ANASTYLOSIS

ANDREA MARRAFFA

Abstract

The research is oriented to the study of the material world of the theatre, explored thought one of its most important and representative component: the mask. It is, ever since, the element of connection between the tangible and intangible world of the theatre, between the solid part and the more emotional, heavenly and magic sphere, that it is able to embody. The mask is, also, the case-study of this project of Research. The theatrical terracotta little masks of the Magno-Greek coroplastica, found in Lipari by Bernabò Brea and M. Cavalier, during the XX sec., represent, until today, one of the most important, widest and completest source of the, so-called, Material Culture of the Theatre. The systematic study and the philological analysis of many samples of the Liparote collection, among intact and fragmentary evidences, offered the chance to carry out an aesthetics consideration about the potential value of the fragment, therefore, to define an articulated methodology useful to the digital reconstruction of these scenic devices. The settlement of a digital protocol of integration and anastylosis, allowed to give back the voice to all those fragments of entire and, those so-called 'silent' fragments. The protocol is oriented, also, to the creation of a new interpretative code for those finds, and it is based on the compilation of a 'genetic grammar' of the mask, structured on macro-groups, families, types, etc. Through this pipeline we tried to restore, not only the material, morphological and formal dimension of the scenic devices in fragments, but also, their historical and semantic memory. In the last part of the Research, we tried to rough out some axes and solutions for the dissemination and valorisation of the finds, by means of the new strategies of Edutainment, the so called 'recreational didactic'. In this section it has been also tested an innovative protocol of annotation and semantic segmentation for the Culture Heritage, and a solution of Augmented, Reality, of Motion Tracking and of Video Mapping, for the improving of the educational entertainment oriented to the museum's world and to the theatre.

La Ricerca si orienta allo studio del mondo materiale del teatro, sviscerato attraverso uno dei suoi elementi più noti e rappresentativi: la maschera. Essa è, da sempre, l'elemento di raccordo fra il mondo tangibile e intangibile del teatro, fra la parte solida e la sfera invece più emozionale, eterea, magica, che esso è in grado di incarnare. La maschera è anche il caso-studio di questo progetto di Ricerca. Le terrecotte di argomento teatrale della coroplastica magno-greca, scoperte a Lipari da L. Bernabò Brea e M. Cavalier nel corso del XX sec., costituiscono, ad oggi, una delle fonti più importanti, copiose e complete della cosiddetta 'Cultura Materiale del Teatro'. Lo studio e l'analisi filologica di numerosi esemplari della collezione liparota, fra reperti integri e frammentari, hanno offerto il pretesto per impostare, in primis, una riflessione estetica sul valore potenziale del frammento, quindi, per definire un'articolata pipeline metodologica, utile alla ricostruzione digitale dei dispositivi scenici. La definizione di un protocollo digitale di integrazione e di anastilosi ha permesso di ridare voce a tutti i frammenti di intero e ai frammenti, cosiddetti, 'muti'. Il protocollo si orienta alla creazione di un nuovo codice interpretativo per tali reperti, e si fonda sulla compilazione di una vera e propria 'grammatica genomica' della maschera, strutturata per macro-gruppi, famiglie, tipi e sotto-tipi. Attraverso questa metodologia si è provato a restaurare, inoltre, non solo la dimensione materiale, morfologica e formale dei dispositivi scenici in frammenti, ma anche, e soprattutto, quella loro memoria storica e semantica, per troppo tempo sopita. Infine, nell'ultima parte della Ricerca, sono stati delineati alcuni assi e soluzioni per la disseminazione e fruizione dei reperti per mezzo delle nuove strategie di Edutainment, la cosiddetta didattica ludica. In questa sezione, sono stati testati particolari protocolli innovativi di annotazione e segmentazione semantica per il Cultural Heritage, e alcune soluzioni di Augmented Reality, di Motion Tracking e di Video Mapping, per il potenziamento dell'intrattenimento educativo, orientato ai musei e, più specificatamente, al mondo del Teatro.

The material culture of theatre: the mask and the rite

The theatre has been a widely studied topic and interest of archaeologists, architects, specialists, architectural historians and theatre historians, examined from various points of views. Nevertheless, what still an open and unexamined research problem is the relationship between theatrical spaces and other tangible and intangible aspects of theatre that fall within the cultural and artistic sphere of the scenic and scenography world. Compositional setup is *frons-scenae*, stages, stage costumes, masks, public spaces, actors' roles, technical innovations, etc. All these entities, which we can define as a complex and articulated 'show machine', allows us to reach the definition of Material Culture of Theatre. All these have been examined, and continue to be investigated, even today, the concept of theatre much wider than what we are accustomed to, given by the material or abstract deployment of its primary elements. The theatre box resurrects as a true volumetric apprehension, "an appendix", that begins to relate the surrounding space and the first and last user of this great scenery: the spectator.

Among various appendices, the mask is the element that probably has a more evocative ability than others, being able to demonstrate the limits, the contact points by giving a code of reading for the order of chaos that exists in the complex reality: architecture, archaeology, and the immaterial of the scenic world. In the Greek world, the term mask was indicated with *pròsopon*, literally face, indicating both the mask and the literary or theatrical character. This parallelism is more clearly found in the Roman theatrical type, which defines its role or character, and is expressed by the Latin word, *persona*. What the mask-face and costume offered both to the interpreter and to the spectator (long-distance recognition, voice amplification, definition of the type of character on the scene and great dynamism in the change of actors), was above all the possibility to implement a distancing processor from fatal and extreme situations,

Fig. 1 - 'The material culture of the Theater', (A. Marraffa & N. Mancuso, 2017)

thus fulfilling the function of diaphragm to control the excess of truth in stage *mimesis*. The masks analysed during this research are those discovered during the excavations of Luigi Bernabò Brea and Madalaine Cavalier, in the Greek necropolis of Lipari of *contrada Diana*, starting from the second half of the 20th century. A huge number of clay findings are indicated by archaeological literature such as

theatrical theme masks, whose production dates vary from the beginning of the 4th century until the middle of the 3rd century B.C. They represent the largest, the richest and the oldest collection of theatrical terracotta, including all kinds of Greek dramaturgy: from Tragedy to Satiric drama, passing from Comedy to Flaky Farce, up to type characters of the Menander's New Comedy.
The masks, probably the result of a very high level of local handcrafts, were re-discovered with votive tombs, and they were probably inspired by prototypes created in Athens. They travelled on board with crates, with the dramatic texts they referred to, less voluminous and bulky than the real ones, made of perishable materials (wood, linen, and stucco) and which are no more in existence today. Luigi Bernabò Brea has grouped them into three different sections according to their chronological order. There is a serial production, extracted by molds, single or double, modified by the skill and craftsmanship of the artisans. The coloration is the best parameter describing the gender: generally darker colours or brownish were used for men, whereas white and lighter colours were selected for women. Almost all the masks have a suspended hole, to be hung as an *ex-voto* to Dionysus, ambiguous God of the mask, of the disguise, God-*pròsopon* with his irresistible gaze, prince of maenads and lords of satyrs god of theatre, of symposia and of the funeral rites. One of the most striking features noted in the Liparian masks is the ability of the craftsmen to suggest the *verismo* characterizing the different characters, as an attempt to make plastically the live contrasting everyone's real feelings. The characters are characterized by a surprising realism of feelings: actually, this happens not only for the masks of tragedy, but also for Comedian's ones, which freeze them at the moment of the highest *climax* of the drama. From the beginning of the 3rd Century. A.C., a new typology of masks spreads in Lipari, corresponding a different *repertoire*, and a new style. It is a more intensive production, evidently intended to the repetition of specimens treat from old tired molds. It also changes the production technique itself: it treats the entire repertory that cover the genre of the New Comedy, partly described by Julius Pollux, Greek grammar of the II sec. A.D., in the IV *Onomasticòn*'s book, a synthetic and descriptive treatise that preserves such of an encyclopaedic vocabulary of the typologies of the theatrical characters represented by the masks. On 44 masks enumerated by Pollux for the New Comedy, there are 9 old men, 11 young men, 7 males, 17 women. It is a well-defined series of character-type, a sample of fixed types and well-known masks that reverberate to Menander and Plautus's works.
The survey on many unbroken and fragmentary masks, allowed to reflect on the compilation of a method of digital anastylosis, through which we could reconstruct many specimens of the theatrical kits studied.

From the photogrammetric survey of the artefacts to the digital protocols for the reconstruction and the anastylosis of the masks

Nowadays the use of modern digital instruments seems to be an indispensable practice for the knowledge, documentation and dissemination of the Cultural Heritage. Therefore, once we defined the preliminary and necessary theoretical state of the art for the theatrical masks of the *Magno-Greek coroplastica*, we thought about the possibility to draw up some methodologies, first of all, for the direct survey of artefacts, then, for their subsequent phases of digital reconstruction and reintegration. The Lipari's theatrical masks may be schematized in three distinct degrees: the entire masks, the fragments of entire and the simple fragments or, also called, the 'mute' fragments. The workflow of reconstruction and digital anastylosis, therefore, respects the decomposition of these three degrees of *status*.
The *leitmotiv* of the protocol was 'thinking as artisans', making a strategic use of the innovative digital techniques. The protocol has a reverse pyramidal structure which from

Fig. 2 - 'Degrees of status' (A. Marraffa, 2017). The three degrees of status of the theatrical masks: the entire, the fragments of entire, the 'mute' fragments

Fig. 3 - 'Forma Personae Liparis and the mute fragments' (A. Marraffa & N. Mancuso, 2017). The Liparian collection, first approaches and an aesthetic theory to rebuilt the fragmentary masks

the general, goes until the detail, gradually tightening the focal to an ever more specific part. If the process of integration and reconstruction of the artefacts has been applied to the most representative terracotta simples, and belonging to all kinds of drama - Tragedy, Ancient and New Comedy, Satyr Drama - on the other side, the pipeline of anastylosis, it mainly focused only on the New Comedy's masks. In addition, the subdivision in macro-groups of comic masks (old men, young men, women, slaves, etc.) and in sub-groups (for example: the *Pappos pròtos*, the vainglorious young man, the parasite, etc.), allowed to orient the protocol to those particular categories that present a higher number of specimens.

So, recapping, the first part of the Research deals with all the adopted digital phases to reconstruct a mask, starting from its state of 'fragment of an entire'. In particular, the workflow is articulated through the following phases: - photogrammetric survey; - data processing (extraction of point clouds); - meshing of models; - study of the main geometries; - philological and bibliographical detailed study for the two-dimensional reconstructive hypothesis; - 3D modeling (sculpting and texturing phases); - texturing, neuter zone criteria and evaluation of the colour dominances. Instead, for the anastylosis protocol, after a

Fig. 4 - 'The digital survey of the fragments' (A. Marraffa, 2017). The image recaps the main steps of the survey of the artefacts through digital photogrammetry

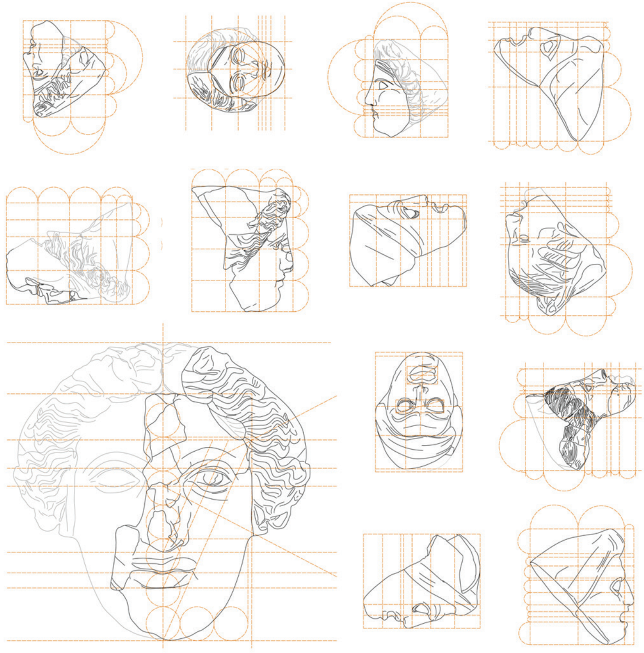


Fig. 5 - 'Masked geometries' (A. Marraffa, 2017). The protocol of integration and reconstruction implies the identification of the main geometries that rule the masks: symmetries, proportions, golden sizes, etc.

first general reconnaissance of all mask groups, starting from the 2D redesign of all the 343 masks New Comedy, we decided to reduce the focus towards the macro-group of young-men, and subsequently on the subgroup n. 12, the so-called 'Young men with wavy hair'. On this subgroup - and in particular on the specimens of the second measure - we were able to define an anastylosis pipeline, with the main aim to build a linguistic code useful to relocate all the mute fragments within a larger compositional scheme, able to including them all. In particular, the anastylosis is focused on the definition of a general prototype 'the super-mask', which is a neutral and generic model, extracted by the weighted average of all measurements drawn on sub-group specimens. Finally on this prototype, we verified the adherence of the mute fragments and also many other parallel considerations useful for the philological and semantic analysis of the finds.

The edutainment

The following part of the Research is oriented to the definition of some methodologies of Edutainment, applied to the *Magno*-Greek mask's universe. The word Edutainment means a liquid kind of cultural offer, at halfway

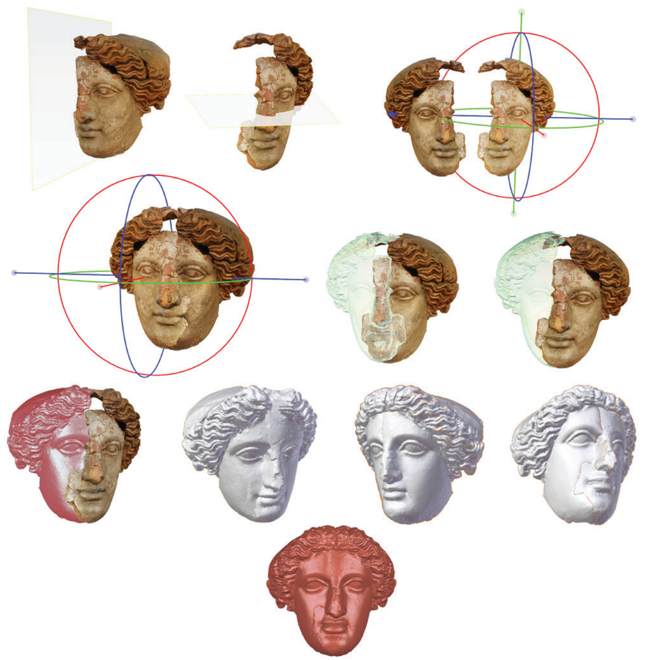


Fig. 6 - ‘The protocol of integration’ (A. Marraffa, 2017): the ‘Dionysus’

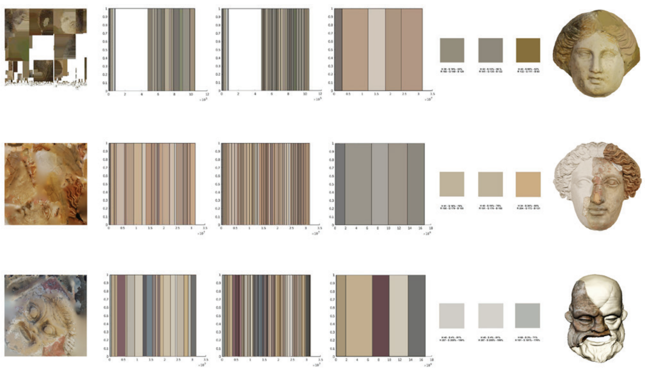
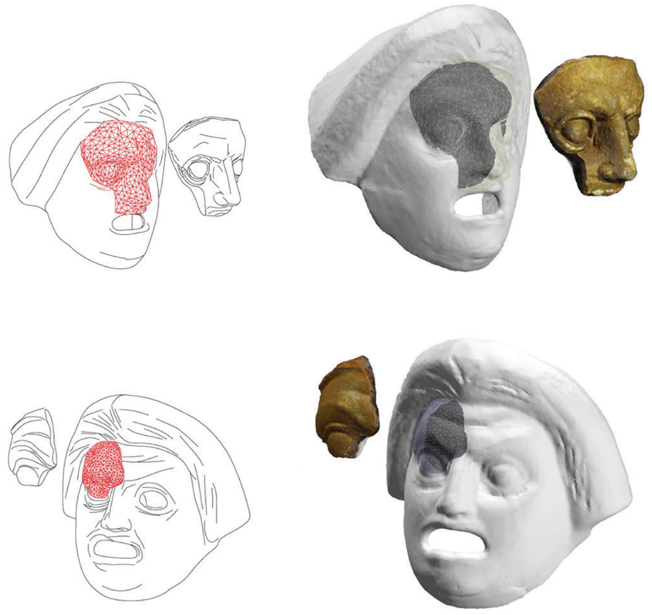


Fig. 7 - ‘The neutral zone criterion’ (A. Marraffa, 2017). Calculation of the master-colour applied for the reconstruction



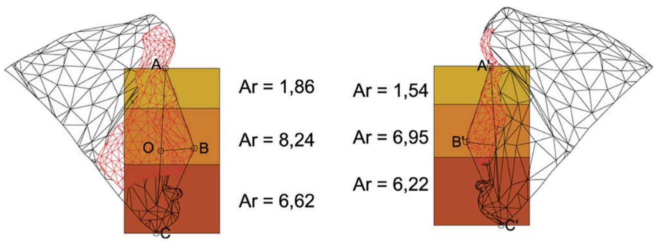


Fig. 8 - ‘The anasylosis’s protocol’ (A. Marraffa, 2017): tests of adherence of the mute fragments of the ‘relative prototype’, the neutral ‘super-mask’ obtained from the average of the main characters of each known artefact

Fig. 9 - ‘The 3D printing’, (A. Marraffa, 2017). The image shows the RGB post-processing of the textures to reach the perfect mimesis with the original mask


ORIGINALE


1. Filtro fotografico più freddo (80) 25
Livelli sx=14 dx=177
Filtro fotografico più freddo (82) 5


2. Filtro fotografico più freddo (82)
Livelli sx= 14 dx = 164


3. Filtro fotografico più freddo (82)
Livelli sx=14 dx=190


4. Correzione colore selettiva
GIALLI (G = 50; M = 30)
MAGENTA (G = 30; M = 30)
Filtro fotografico più freddo (80)
Livelli sx =14 – dx = 150


ORIGINALE


1. Filtro fotografico più freddo (80) 25
Livelli sx=14 dx=177
Filtro fotografico più freddo (82) 5


2. Filtro fotografico più freddo (82)
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3. Filtro fotografico più freddo (82)
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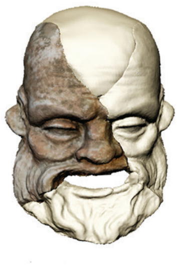
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3. Filtro fotografico più freddo (82)
Livelli sx=14 dx=190


4. Correzione colore selettiva
GIALLI (G = 50; M = 30)
MAGENTA (G = 30; M = 30)
Filtro fotografico più freddo (80)
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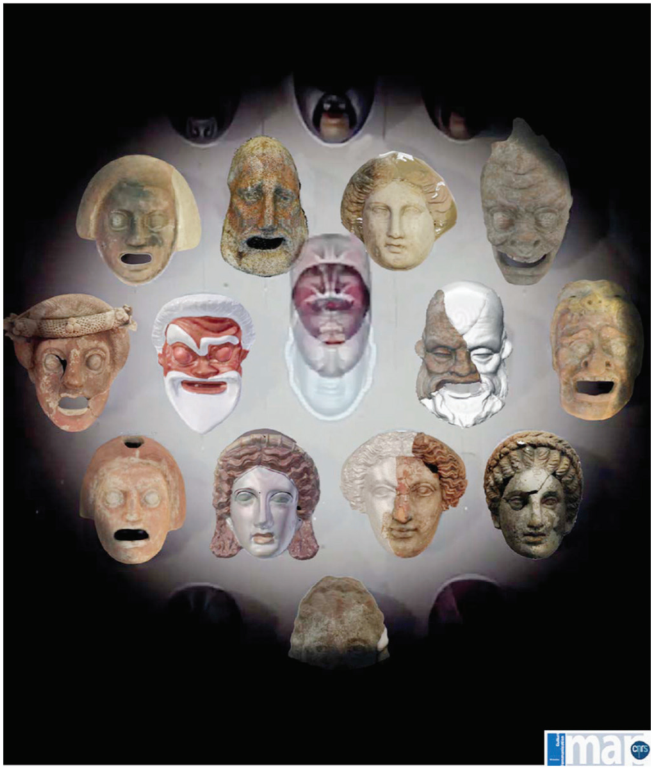
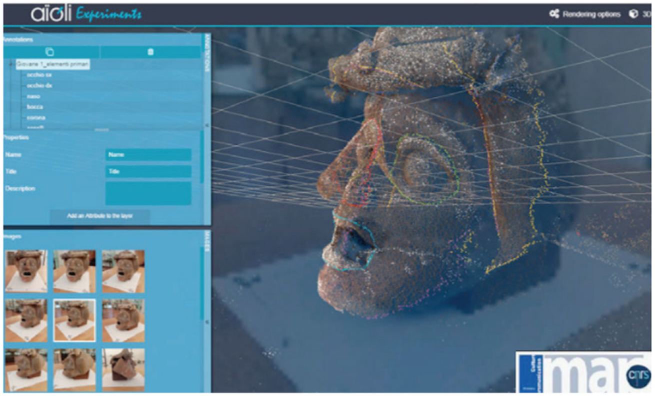
between education and entertainment. These solutions have been thought to adhere to different cultural contexts: from the scientific dissemination for the museums to the recreational activities for the theatre, from the choice of a semantic tool for the pedagogical and didactic valorisation to the studies about the design and the ergonomics of our theatrical devices, finalized to their modern reuse in the theatres.

From the 3D prototyping to the tactil museum

With the aim to define a tactile and multi-sensorial path, available for everyone (users with or without visual disability), we printed some of the most significant artefacts of the Liparian collection. Among them, we chose the sample that better than others condensed all the step developed during the protocol of reconstruction and anastylosis. Therefore, we printed some entire samples, some fragments of entire, and some 'mute' fragments.
It is important to underline that the design of a tactile and multi-sensorial museum does not aspire to replace the traditional cultural offer. Quite the opposite, the main objective is to juxtapose to the current collection, increasing it through some new more interactive and captivating systems of fruition and dissemination.
From a side, the three-dimensional printing allows to have models with a high morphological accuracy, however on the other side, this does not work as well for the chromatic yield. With the aim to guarantee a more accurate hicastyc *mimesis* of the original artefact, we made many colour testings, printing at the same time many copies of the same model, but using a reduced size. All the textures, extracted from the photogrammetric survey, undergo some post-processing modifications, through the application of filters, warmer or colder than the original texture. Then, each texture was applied on many copies of the same 3D models. So, each artefact was compared with the original one, and we chose the copy that, more than the others,





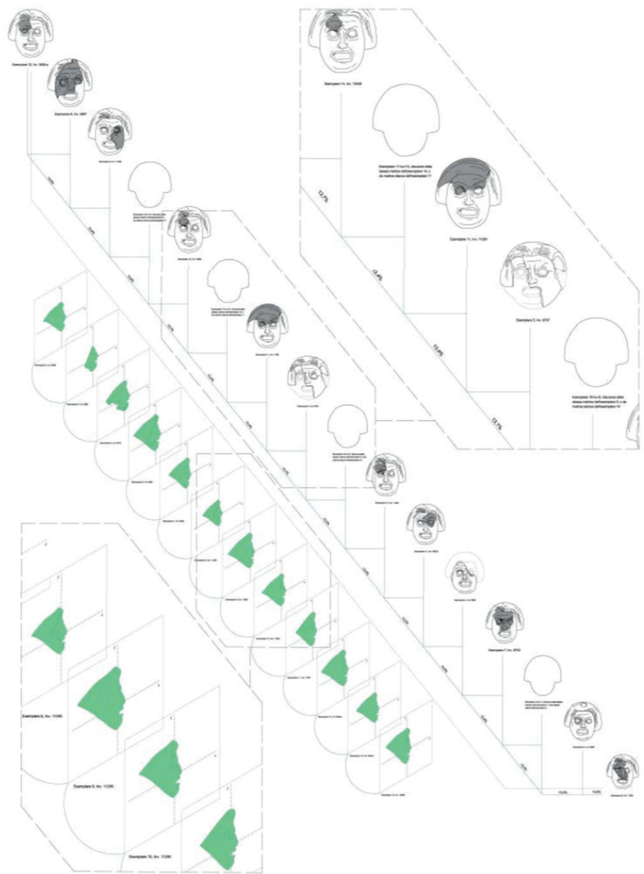


Fig. 10 - 'The semantic description' (A. Marraffa and MAP-CNRS of Marseilles, 2017). Segmentation and annotation of some samples of masks, Aioli

Fig. 11 - 'The semantic tree-system', (A. Marraffa and MAP-CNRS of Marseilles, 2017). A phyllo-genetic structure: it leads all the semantic description of each mask's samples

looked like the original one.
It is good to remark two important aspects: some models, in particular the fragments of entire of the Dionysus and of the *Hethera*, were printed in one single-piece, with the relative part rebuilt whose we applied an under-tone of colour, with the aim to guarantee the recognition of the integration. For the other fragments of entire, for example the *Pornòboskos*, we decided to print two separated pieces: one for the original fragment and the second one for the related integration. We also thought about a magnetic system to make possible the coupling of the reconstructed part and the original fragment. This aspect guarantees the independence of the fragments in relation to the entire, and at the same time it allows immediately to return to the unity. In this way, we respected two important theoretical objectives for the restoration: the recognition of the intervention and the reversibility of the reconstruction process.

Some methodologies for the annotation and the semantic description of the masks

With the aim to guarantee a semantic analysis of the huge Liparian mask's universe, we decided to use an innovative web-platform for the semantic annotation. This web-platform is known as Aïoli. The software, tested at the *CNRS*'s *MAP* laboratory of Marseilles, is a cloud collaborative service for the 3D annotation, that allows to process many three-dimensional representations through some automatic photogrammetric tools, enriching them with semantical descriptors, called denominations or labelling. These descriptors have the aim to improve the comprehension and the analysis of the studied artefacts. Aïoli was tested on all the samples of masks (entire, fragments of entire and 'mute' fragments) of the New Comedy. We defined a hierarchical schema of calques, and we draw up so many layers how they were the semantic descriptors to connect. For each sample of mask, we extracted many information

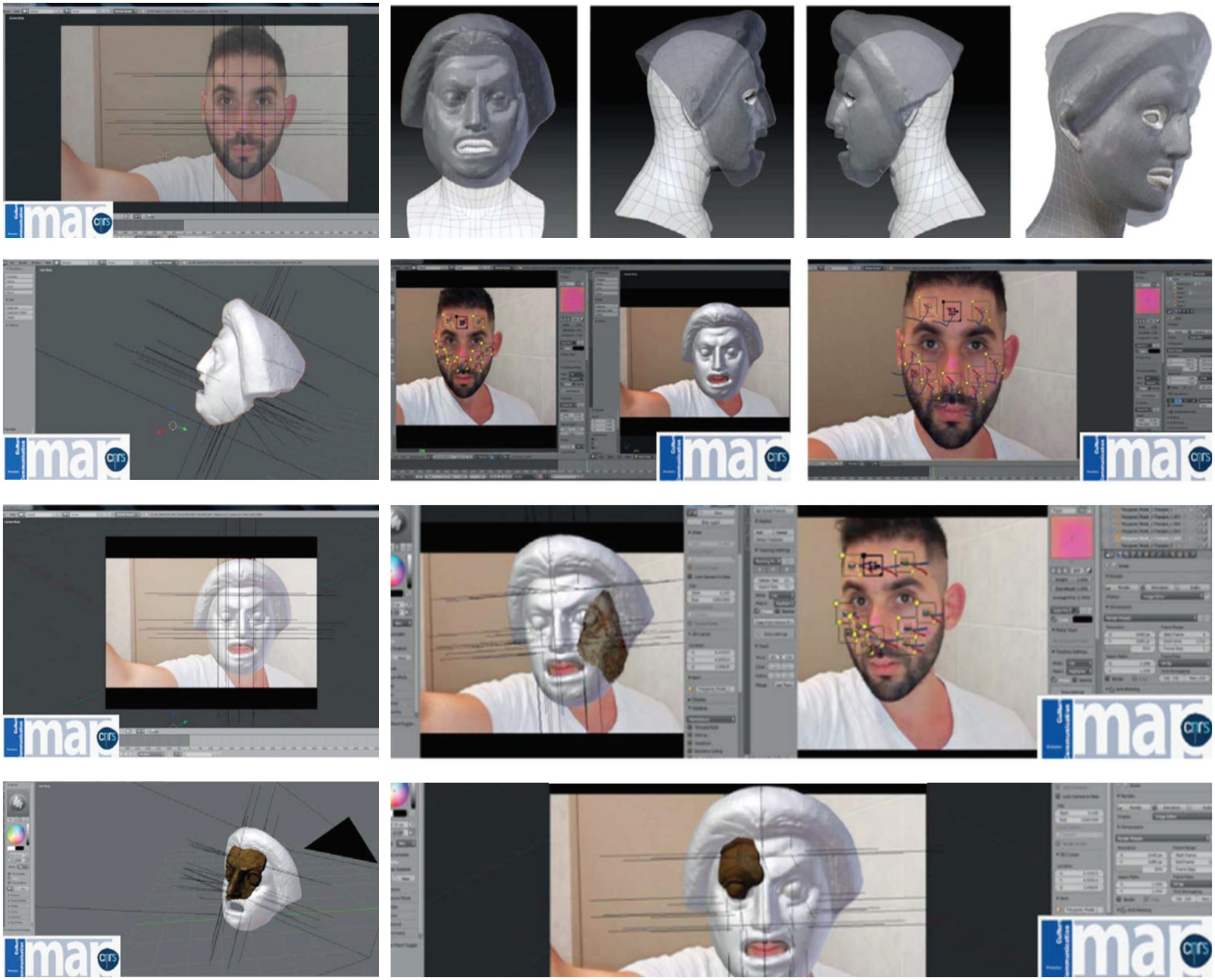


Fig. 12 - 'The Edutainment: the didactic entertainment', (A. Marraffa and MAP-CNRS of Marseilles). This image shows some different methodologies for the dissemination of the Research. The Edutainment has got the aim to reintroduce the mask in the modern world: the tactile path, the motion tracking for the museums and the video-mapping for the theatre.

about the morphological and geometrical features of the artefacts, functional for the qualitative and quantitative comparison between a sample and the other. Among all these information, we may mention: the complex vertical profiles, the bending radius of the main elements (mouth, eyebrows, cheeks, nose, eye), the quantitative analysis of the primary elements comported to the entirety of the artefacts, the main distances, etc. Starting from a precise shape grammar, constituted by all the primary characters, remarkable on each model, we were able to define a sort of hierarchical clustering for the macro-typologies of masks and of their main morphological elements. This typology of structure - also called ‘tree-system’ - has got a phyllo-genetic structure, and it leads all the semantic descriptions, and it helps to define a continuous workflow of information, codified in only one coherent source. This methodology, with a huge technological pregnancy, but at the same time equipped with a strong artisanal character, allows to obtain real ‘talking’ models, thanks to their multi-resolutions. The labelling and the semantic description seems as a necessary process for the Cultural Heritage’s documentation, and they represent an indeclinable approach for the completest and widest communication and dissemination of the Cultural Heritage.

The Augmented Reality and the new digital media

How we already said in the previous paragraphs, the cultural spaces became, always more, a complex business, operating within a new cultural economy that is in constantly evolution. Nowadays, the Cultural Heritage’s business is variegated but also very saturated, because it is still linked to a too slow and passive communication, unable to encourage the final customer’s participation. There are still few museums that choose to wager on the digital way with the aim to integrate the traditional offer, setting up all the modern and interactive technologies to create some new story-telling for a more complete dissemination of the Cultural Heritage.

For all these reasons, beside the creation of a multi-sensorial and tactile path of the mask, described in the previous paragraph, we also thought some other Augmented Reality’s solutions, condensed in the Motion Tracking and in the Face-Video Mapping, with the aim to guarantee a faster and a more captivating fruition of the analysed artefacts, customizing and regulating the visit on the base of the necessities and interests of each visitor. We developed these AR solutions to respond to multiple contexts, characterized by different declinations: form the classical dissemination for the museums, to the didactic for the academicals-scientific area, from the serious gaming to the fruition for the show business, for the entertainment and for the theatrical and architectural scenes.

Conclusions

The main objective of the Research was to study analytically a large part of the collection of Lipari’s masks, with the aim to draw up a protocol of integration, anastylosis, and dissemination of the most representative specimens. This study has also allowed to arrive to further specific conclusions: 1) the first one, in a theoretical sense, asserts that it is possible to talk about the existence of a Material Culture of the Theatre. It is an essential part of the theatrical world. Its presence is crucial to triggering all those mechanisms of sewing between the tangible and the intangible culture in the scenic arts world; 2) it has been defined a complete and universally workable pipeline, applicable to all the fragments of entire and to all the ‘mute’ fragments. It considered all the main cases and the problems that the fragmentary state involves. As we already explained, this protocol is potentially applicable also to other areas, different from those of the archaeological area. In fact, the methodology, which follows the logical line of ‘digital scanning of the finds/modeling by means of integration/construction of the anastylosis’s pathway’ may be conducted, for example, also on the fragments of the ruined architectures, for which it is possible to re-establish a historical lost memory. In addition, the segmentation and semantic description steps are particularly indicated when it comes to deal with complex assets of Cultural Heritage, for which it is necessary starting a schematization in hierarchical structure or into clusters, progressively more sectorial and specific; last but not the least, we developed some innovative methodologies useful for the dissemination, the fruition and the valorisation of the scenic devices, for their reusing and overhaul in the modern museums and in the contemporary theatres, through virtuous, innovative and interactive approaches of Edutainment.

Notes

[1] Thanks to the *pròsopon*, the actor was able to assume a different and an autonomous identity. During the Classical period, the word *pròsopon* was used to identify simultaneously the mask and the face. Cf. Wiles, D., (1991). *The Masks of Menander. Sign and Meaning in Greek and Roman Performance*. Cambridge: Cambridge University Press, pp. 22-24.

[2] Cf. Bernabò Brea, L., (1981). *Menandro e il teatro greco nelle terrecotte liparesi*. Genova: Sagep Editrice, pp. 11-14.

[3] About the material used to make the theatrical masks, cf. Baldi, H.C., (1987). *I greci a teatro. Spettacolo e forme della tragedia*. Roma-Bari: Laterza, p. 80, e Albini, U., (1991). *Nel nome di Dioniso. Vita teatrale nell'Atene classica*. Milano: Garzanti, p. 24.

[4] Cf. Bearzot C., Landucci, F., Zecchini, G., (2007). *L'Onomasticòn di Giulio Polluce. Tra lessicografia e antiquaria*. Vicenza: Vita e Pensiero, pp. 8-24.

[5] The word Edutainment is a neologism, coined by Bob Heyman in 1973. The term is composed by two English words: 'education' and 'entertainment'. These are the two main objectives for the cultural communication: the educational path and the recreational one. Cf. Cervellini, F., Rossi, D., (2011). *Comunicare emozionando. L'Edutainment per la comunicazione intorno al patrimonio culturale.* In 'Disegnare con, Tecnologie per la comunicazione del patrimonio culturale'.

[6] Aïoli is project presented by the MAP lab, *CNRS/MCC* during the *Salon de la Valorisation en Sciences Humaines et Sociales, Palais de l'Europe,* Marseilles, May 2017.

[7] The annotation and the semantic segmentation are two taxonomic that allow to connect many different kind of information linked to the Cultural Heritage (historical information, philological/iconographical/morphological data, etc.). Each artefact is considered as a huge cognitive system, able to contain thousands of information. Cf. Slimani, T., (2013). *Semantic Annotation: The Mainstream of Semantic Web*. In International Journal of Computer Applications Technology and Research, Vol. 2. N.s.: *Issue* 6, pp. 764-770.

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09 DIGITAL ANASTYLOSIS FOR DIGITAL AUGMENTED SPACES: SPATIAL AUGMENTED REALITY APPLIED TO CULTURAL HERITAGE

DONATO MANIELLO

Abstract

Thanks to the use of digital media, which is increasingly present in contemporary museography, the concept of anastylosis, and consequently its use, can be reviewed in the light of the results achieved to date in narrating heritage. The aim is to make the understanding of evidence in the field of archaeology and art history, which is often fragmented, more accessible. The anastylosis of such evidence can be enhanced both through digital reconstructions and the possibility of integrating them through a video projection, that makes use of SAR (Spatial Augmented Reality), directly onto the artefact, allowing appreciable and interesting levels of understanding of it to be reached. The transformation of spaces into knowledge-sensitive environments allows a perfect and natural hybridisation of analogue and digital technologies. The versatility of this technique - albeit with some limitations – allows correction and addition of all information that the advance of the studies and researches can bring over time, with relative operational simplicity. The restored and rebuilt portions, in fact immaterial and in compliance with the scientific transparency of the data, will be based on interdisciplinary studies and research in order to not alter the meaning of the artefact (considering the ease with which this information can be manipulated), thus giving a degree of accuracy that guarantees scientificity. In particular, this contribution will focus on the use of SAR in two specific case studies, in order to highlight the limits and potential of this hybrid technology; this discussion will take place in light of the ever current issues on virtual archaeology expressed both in the Charter of London and in the Principles of Seville. Digital anastylosis is a further tool of knowledge, which can thus favour the process of appropriation related to cultural heritage without this compromising conservation needs.

Grazie all'uso dei mezzi digitali - sempre più presenti nella museografia contemporanea - il concetto di anastilosi, e di conseguenza il suo utilizzo, possono essere rivisti alla luce dei risultati ad oggi raggiunti per narrare i beni culturali. Il fine è rendere più accessibile la comprensione delle testimonianze nel campo dell'archeologia e della storia dell'arte, spesso frammentarie. L'anastilosi di tali evidenze può essere potenziata sia tramite ricostruzioni digitali sia dalla possibilità che queste siano integrate attraverso un sistema di video proiezione che sfrutti la SAR (Spatial Augmented Reality) direttamente sul bene stesso permettendo di raggiungere livelli di comprensione del manufatto apprezzabili e interessanti. La trasformazione degli spazi in ambienti sensibili alla conoscenza permette una perfetta e naturale ibridazione delle tecnologie analogiche e digitali. La versatilità di questa tecnica - seppur con alcuni limiti - consente infatti la correzione e l'aggiunta, con una relativa semplicità operativa, di tutte quelle informazioni che l'avanzamento degli studi e delle ricerche possono nel tempo apportare. Le porzioni ripristinate e ricostruite, di fatto immateriali e nel rispetto della trasparenza scientifica del dato, saranno basate su studi e ricerche interdisciplinari al fine di non alterare (considerando la facilità con cui è possibile manipolare tali informazioni) il significato del manufatto conferendo così un grado di accuratezza che garantisca scientificità alla comunicazione. In particolare il presente contributo si focalizzerà sull'utilizzo della SAR su due casi di studio specifici al fine di mettere in luce limiti e potenzialità di questa tecnologia ibrida; tale discussione avverrà alla luce delle sempre attuali questioni sull'archeologia virtuale espresse sia nella Carta di Londra che nei Principi di Siviglia. L'anastilosi digitale si configura come ulteriore strumento di conoscenza che può favorire quindi il percorso di appropriazione relativo all'eredità culturale senza che ciò ne pregiudichi le istanze di conservazione.

Introduction

One of the achievements that was reached thanks to the advent of digital technology, while not free of problems, is the undisputed ease with which it is possible to correct the virtual representation of any object. If this characteristic is translated into the world of cultural heritage, one of the most acute problems in the field of restoration and reconstruction - reversibility - can be resolved. The terminological debate on the association of the terms 'restoration' and 'virtual' has already been extensive, which in fact has been defined by some theorists as an oxymoron as it is "a technique which, operating on the image of the document and not on the original, does not have the characteristics or the purposes of material restoration"[1], whose purpose is to intervene physically and materially on the artefact.

However, this has not prevented "virtual restoration"[2] from carving out an ever-widening space among scholars, since 'virtuality', and even more so the digital world from which it springs, has been credited as a 'weight of data' and in a certain sense a 'materiality of information'. This is because, as noted by some scholars: "numbers, images, sounds and whatever else is produced on a computer must be understood as a new kind of materiality, which has its physical consistency and its domain of belonging and circulation. Just like real objects, three-dimensional models and digital images express a measurable spatiality, physical and chromatic values, and can be transformed into 'tangible' objects via prototyping techniques. But more importantly, they exist."[3]

Conservation and restoration can therefore, even if ascribed to the virtual world, be considered a valid tool to support traditional conservation and restoration, since those who work in it do so within methods, rules and principles that are the result of a tradition and a debate that sees the bedrock of the transmissibility of this heritage to the future in the various Restoration Maps.

The issues expressed by the Charter of London, in particular in a passage from Principle 2, which states that "a method of digital visualisation should normally be used only when the method is available and most appropriate for that purpose", must always be taken into account in relation to the opportunity that the cultural object in question has to be genuinely communicated and enhanced by the multimedia action. Furthermore, in the evolution of the concept of restoration, the need to control - or rather to halt - the creative act in favour of pure conservation has been a relatively recent achievement and anastylosis too - even more because it is understood digitally and therefore easily modifiable - must also follow a rigorous process of verifying sources and results[4].

Anastylosis: indirect, computer science, digital.

Anastylosis is a restoration technique used in archaeology, consisting of reconstruction obtained through recomposition, using the original pieces of ancient structures. Based on the recommendations dictated by the Athens Restoration Charter of 1931 (Article 4), anastylosis is considered a desirable reconstruction technique wherever conditions permit, and is the only scientifically acceptable technique. This position was reiterated in art. 15 of the 1964 Venice Charter which indicates the initiatives that can facilitate "the understanding of the monument brought to light, without ever distorting its meaning. All reconstruction work should however be ruled out 'a priori'. Only anastylosis, that is to say, the reassembling of existing but dismembered parts, can be considered acceptable. The elements of integration should always be recognisable, and limited to such a minimum necessary to ensure the conservation of the monument and restoration of the continuity of its forms". Any integration that should become necessary must be distinguishable from the ancient parts, in order to not obscure readability. Anastylosis can also be indirect[5], that is used more as a museum presentation technique than for reconstruction[6]. In the case of scarce and discontinuous fragments, which are however all

Fig. 1 - Caryatids and clypeus with head of Jupiter Ammon of the attic of the portico of the Forum of Augustus, Museo dei Fori Imperiali, Rome

pertinent to the same artefact, it is possible, after an accurate historical-archaeological study, to relocate them and present them again in the position that they had originally had, holding them up with a modern support that could well allude to the ancient shape. In cases where it is not possible to use original remains for reconstructions, the technique of museological reconstructions is helpful, which makes it possible to hypothesise the gaps based on remaining elements.

The field of museographical reconstructions is very fascinating and vast and uses various techniques to reconstruct the missing parts of an artefact for our better understanding. The means and the ways of interacting with it change, but the goal remains the same: to communicate its story as completely as possible. For example, at the Museo dei Fori Imperiali[7] in Rome there are various museographical restorations that have great communicative potential. This is the case of the recomposition of the Caryatids and clypeus with the head of Jupiter Ammon, of the attic of the Forum of Augustus (Fig.1), which was executed with twelve original fragments and additions in Aquila stone and resin[8].

The goal of computerised anastylosis is instead to reassemble a - usually substantial - collection of fragments, collected and catalogued after a destructive event, using appropriate software. In this way it is possible to map fragment positions through computer image recognition techniques that make use of artificial intelligence protocols, in particular machine and deep learning techniques, suitable for the restoration of destroyed frescoes, in order to establish how much of the original work it is possible to truly reconstruct, and evaluate the quality of the final result[9].

One example of this would be the virtual reconstruction intervention followed by an anastylosis reconstruction by of the Ovetari Chapel in Padua, with a cycle of frescoes by Andrea Mantegna[10] (Fig.2), whose visual documentation of the results obtained had the aim of giving meaning to the innumerable fragments of a marvellous work that the war irreparably damaged.

Digital or virtual anastylosis has many points in common with information technology and is essentially its brainchild. It differs in the non-automation of the process of recognising gaps, repositioning and reconstruction. The operator uses the digital tools at his disposal, performing the reconstruction through the application of new technologies, with the support of the interpretation of data from documentary sources, and previous studies, for

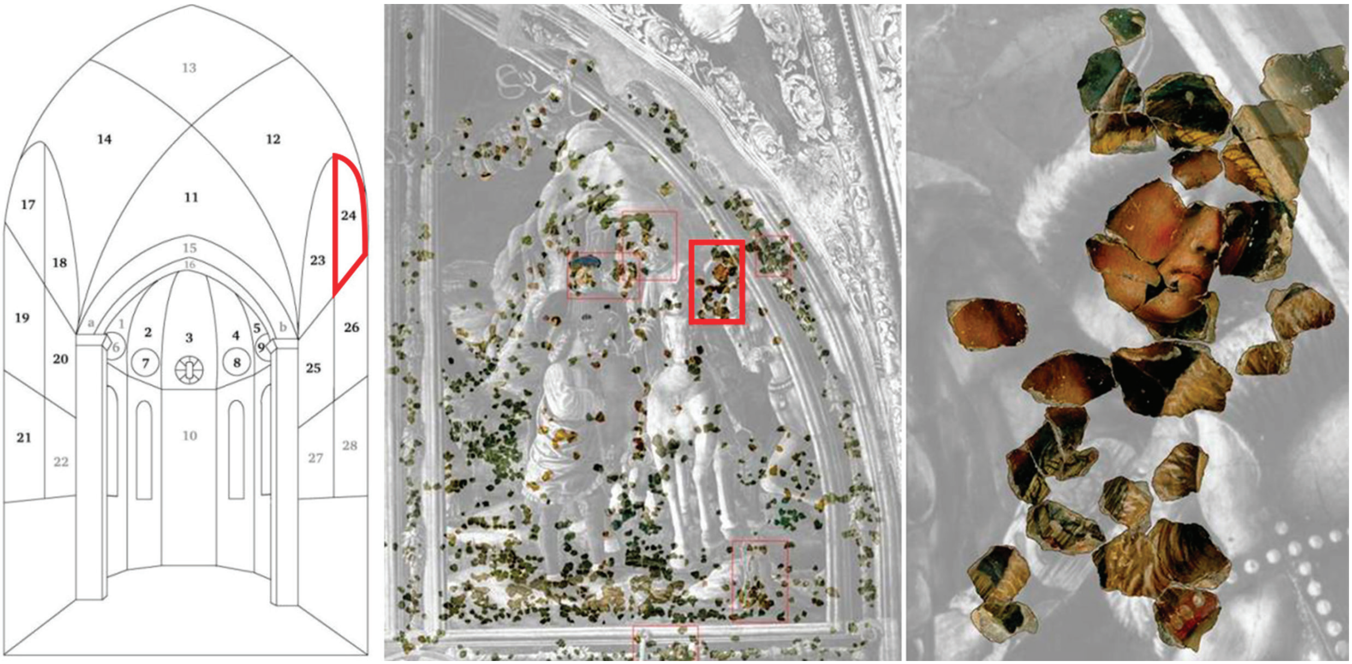

Fig. 2 - St. Christopher and the King of the Demons (from the general to the particular).

recognising fragments and / or images which are useful for hypothesising a final result. Reconstruction does not only concern buildings or structural parts of them, but also concerns artefacts and fragments, through systems which are able to digitally transpose and virtually replicate the traditional methods of recomposition and assembly, used in the past by manual means. The advantages of digital anastylosis, in those cases where it can be foreseen, include the following:

- The possibility of working with fragments without physically operating on them, with the consequent risk of further damage;
- The possibility of evaluating the result of the anastylosis before moving on to the actual reconstruction;
- The possibility of using diagnostic imaging to enrich knowledge of the building and expand the narrative levels and the history of the cultural heritage, for example hypothesising the original colours.

Limits and potential of digital anastylosis in augmented environments

The SAR[11], given its projective characteristic, does not reconstruct spaces unless they have been volumetrically replaced, so as to allow video projection to take place. Its characteristic is in fact to project onto surfaces. It can then be used to reconstruct the material appearance of the blocks, the colour and the original texture. The fact that it can be used on three-dimensional structures is a consequence, given that volumes and surfaces correspond

in a one-to-one correspondence.
The possibility of observing such reconstructions in situ, capable of 'increasing' information through a projective video system - a characteristic of SAR - gives anastylosis, digitally interpreted, one of the most important communicative potentials of all digital tools which are available today. In fact, the user is involved in an 'enhanced environment' with the characteristic of making it free from any other electronic device.
Anastylosis and SAR share a very interesting aspect, which is the possibility of 'enhancing' the structures/surfaces on which they project - the former with physical materials and the latter with digital instruments, thus pursuing a similar purpose: to communicate the original form as completely as possible, and therefore the history of that artefact. Finally, if both are used synergistically, the communicative potential of one strengthens the other's potential in a complementary manner. The increasing use of this medium in museums and in archaeological parks is mainly due to both the relative ease of approach to the communication of even quite complex themes, and to the complete reversibility and even updating, where the research foresees it, but above all to the inclusiveness experienced during the enjoyment.
However, this technique is not exempt from certain limitations. In anastylosis understood in the classical sense, turned for example to buildings, reconstruction guarantees the material contiguity of architectural elements, also using large blocks (whether they be of the original material or reconstructed). From this it follows that in order for digital anastylosis via SAR to take place, a preliminary reconstruction of the parts is necessary, albeit temporary.

Digital anastylosis in contemporary museography

SAR is a technique with unquestionable advantages when used for the purposes of indirect anastylosis on ancient surfaces, such as those of frescoes and paintings[12] but does not fail to amaze even when it is applied to three-dimensional structures such as monuments. The fundamental principle of these interventions is their full reversibility, which allows the completion of the re-compositions with possible new discoveries which may emerge following the progress of excavations and archaeological studies, with the aim of reconstituting the visual unity of the materials. Finally, we must consider the fact that due to painted narrative rules and symbols, it can often be complex, for the user that is not aware, to discern their meaning or to focus attention on elements of importance if only one classic type of communication is used (such as captions or verbal narration). This is the reason why digital anastylosis is a strength. The following examples share these characteristics: they are frescoes; most surfaces are compromised or non-existent; a reconstruction had been hypothesised; an inclusive experience of enhancement is favoured thanks to the absence of devices. Does the public respond favourably to these new forms of communication? Specific evaluation surveys are not always available. But in the case in which they are present, such as for Sant Climent de Taüll, these changed radically in 2013, when the digital enhancement project was launched. While in the second case, relating to the installation present at the Cerbero Hypogeum, since a campaign concerning access data was never prepared before the enhancement intervention, it is not possible to provide a single answer except that it reports a significant increase in requests to visit the site, following the creation of the permanent installation.

Sant Climent de Taüll, Spain

Among the churches in the Boí Valley - declared a UNESCO World Heritage Site in 2000 - the best known is undoubtedly Sant Climent de Taüll, mainly thanks to its Romanesque wall paintings dating back to the 12th century. In particular, the original painting relating to the

Fig. 3 - Phases of the valorisation work

Christ in Majesty of the apse is currently preserved at the Museu Nacional Art de Catalunya (MNAC) and in 1959 a copy was placed in its original position. In 2012 this copy was in very poor condition, as was the general state of the church, giving rise to a proposal for restoration and enhancement. The proposal to create a new physical copy was quickly discarded when, after removing the copy, traces of wall painting were detected on the walls that confirmed the fragile state of conservation of the underlying images. It was decided to use SAR, with a visual narration only. The original frescoes in the main apse have been recreated according to the studies of a team of scholars[13], who suggested the volumetry and styles of the original paintings. The work was planned in three phases: the restoration of the frescoes currently in situ; the projection of the paintings preserved at the MNAC on the still-existing fragments so as to allow the visitor to contemplate reality as if the paintings had returned to their place of origin, and finally the presentation of a hypothesis on how the paintings were in 1123[14] (Fig.3). The original frescoes were recreated in this way in the main apse and the presbytery of the central nave in order to enhance the architectural and pictorial qualities: for example the figures of San Clemente and San Pietro on the pilasters, or the scene of Cain and Abel in the presbytery (Fig.4). The data relating to visitor admissions demonstrate the success of this intervention in incentivising visits to the site[15](Fig.5).

The fresco of the Hypogeum of Cerberus in Canosa di Puglia

This project is the beginning of a series of interventions - conceived, curated and carried out by Studio Glowarp[16] in collaboration with the Fondazione Archeologica Canosina - aimed at the study of ancient Canosine polychromy[17] through actions of enhancement and communication with digital technologies.

Particular attention has been given to a group of hypogeums in the city, whose compromised conservation status and fragmentary visual information allows us to experience the use of SAR in contexts to which it has never been applied before. The experimentation was made possible thanks to

Fig. 4 - The paintings hypothesised and recreated thanks to SAR. as they must have appeared in 1123

the assent of the Superintendence of Archaeology, Fine Arts and Landscape for the provinces of Barletta-Andria-Trani and Foggia while the hypothesis of reconstruction of the frieze started with previously conducted studies[18].
In southern Italy there are no cases of a similar use of this technology to date[19], although it is now increasingly used in museum and historical-archaeological contexts[20]. Before this intervention, no type of enhancement on the site had been carried out in order to spread the knowledge and the meaning of the frieze, except through the work of local tourist guides who told the meaning orally.
The Hypogeum of Cerberus (Fig.6), so defined because of the mythological three-headed dog that distinguishes it, is characterised by a frescoed frieze of rare beauty, which is present on one of the façades of the four burial chambers and half of which is partially destroyed (Fig.7).

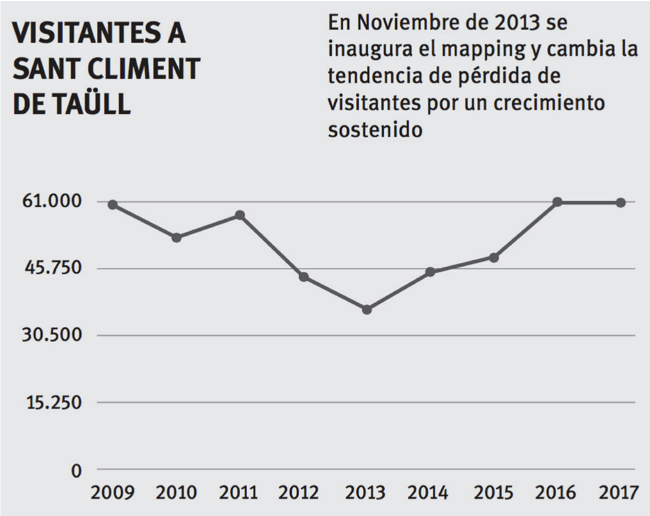

Fig. 5 - Graph of visitor trends at Sant Climent de Taüll (in Albert Sierra Reguera, Estudios de casos en mappings, 3D y realidad virtual en el patrimonio medieval Mappings, 3D and virtual reality in medieval heritage. Humanidades Digitales: Miradas hacia la Edad Media (De Gruyter: 2019), p.242)

Fig. 6 - Hypogeum of Cerberus, dromos

Fig. 7 - Detail of the frieze, pre-intervention.

Fig. 8 - Hypothesis of video reconstruction projected through the SAR technique onto the entire surface. Notice the removable structure at the top to allow the video projections to take place.

Via allusive, symbolic and evocative elements it narrates the passage of the deceased from the earthly dimension to that of death. Digital anastylosis through SAR has enabled an immediate communicative approach, considering the amount of information contained in the frieze it and its fragmentation. The missing surface due to the absence of half of the surface was filled using a removable structure, thus reconstructing the geometry and returning the necessary material unity so that the video projections could take place throughout the frieze area (Fig.8). The creation of a documentary based on digital storytelling, of about five minutes in length, using S.A.R. to describe the meaning of the paintings, seemed to be the most suitable and least invasive approach to communication in relation to the purpose of the intervention and the delicate spatial conformation of the hypogeum[21].

Conclusions

Anastylosis through SAR marks the beginning of a digital museography that combines the 'spectacular' element of digital technology with the illustrative appeal of analogical reconstructions where provided. The use of digital tools certainly represents a valid tool in the hands of scholars, and the examples mentioned demonstrate how digital anastylosis has great communicative potential despite its simplicity. The narrative dimension of the surface and the supporting technology becomes an ideal combination, so that the former is revealed by the entire communicative potential of the latter. The last decade has seen an unprecedented and widespread use of digital communication that is itself a process, and a way to exchange information according to the rules of a specific code that seeks to bind, build and associate. The 'low tech' expressive tools, such as recompositions which are already known in museographic field, can be hybridised to the technology to 'increase' the environments as necessary. However, some critical issues persist, already highlighted by other authors[22], in cases where an artificial aesthetic emphasises dramatisation and forced edutainment may have the upper hand over historical reality. If indeed in the creation of digital narratives "the material support is not used correctly, installation becomes a cinema in the wrong place, and if the dialogue between support and technique is interrupted, the support itself disappears, swallowed up by the video projection or by the projection itself"[23].

The need to contain the creative impulse in favour of correct narration - a problem that is already known in the field of restoration - becomes even more relevant in the digital field: the relative ease with which it is possible to create and modify virtual scenarios goes hand in hand with the risk of encouraging a reading method too aimed at spectacle and less at the scientific nature of the contents. Interesting and not yet fully explored solutions can arise from the continuous interchange between analogue and digital systems, in order to obtain future innovations aimed at the transmission of knowledge. By always maintaining research and scientific knowledge first and foremost, and experimenting with the possibility of connecting to forms and ideologies of the past through the narrative, this type of action can lead to a new conception of the cultural experience, for the benefit of both the users and the conservation and the dissemination of cultural heritage values.

Notes

[1] Cit. Moschini 2001.

[2] Cf. Limoncelli 2011.

[3] Cit. Gabellone 2010, p.497.

[4] Cf. Gabellone 2012.

[5] Source: Wikitecnica, Anasitilosi di Giovanni Carbonara. http://www.wikitecnica.com/anastilosi-diretta-indiretta (accessed on 2 July 2019).

[6] An example of this is the revival, in the Museo della Crypta Balbi in Rome, of the stucco covering of a Roman-era pillar on a modern metal support.

[7] Source: Museo dei Fori Imperiali, Le ricomposizioni. http://www.mercatiditraiano.it/it/percorsi/percorsi_per_temi/le_ricomposizioni (accessed on 2 July 2019).

[8] Source: Museo dei Fori Imperiali, Le ricomposizioni. http://www.mercatiditraiano.it/it/percorsi/percorsi_per_temi/le_ricomposizioni (accessed on 2 July 2019).

[9] Cf. Fornasier 2016.

[10] Source: Laboratorio Mantegna, Strumenti.
http://www.progettomantegna.it/strumenti.html (accessed on 2 July 2019); Cf. Fanin et al. 2000.

[11] Cf. Maniello 2018.

[12] It is necessary to allow compliance with the maximum illumination of 150 lux, indicated in the Atto di indirizzo sui criteri tecnico-scientifici e sugli standard di funzionamento e sviluppo dei musei (DM 10 Maggio 2001).

[13] Design and direction of the project: Eva Tarrida i Sugrañes (Architect), Eduard Riu-Barrera (Archaeologist), Albert Sierra Reguera (Historian).

[14] Source: Mapping Pantocrator, San Clement de Taüll 1123. http://pantocrator.cat (accessed on 2 July 2019)

[15] The increase in the number of admissions starting from 2011, as indicated in the graph in figure 5, could also be interpreted as a general recovery from the global economic crisis that has also affected the culture sector, stimulated by the curiosity connected to the digital media used; Cf. Sierra Reguera 2019.

[16] The creation of the storytelling is courtesy of Dr. Valeria Amoretti, anthropology official of the Archaeological Park of Pompeii, while the multimedia contents and storyboards were entrusted to Studio Glowarp.

[17] Cf. Maniello et al. 2018.

[18] Cf. Corrente 2015.

[19] The multimedia path was inaugurated at the scientific high school "E. Fermi "on 20th December 2018 and was conceived as a permanent one.

[20] Cf. Maniello et al. 2016.

[21] Source: Ipogeo del Cerbero. http://www.glowarp.com/arim_96_ipogeo_cerbero.html (accessed on 2 July 2019)

[22] Cf. Guzzo et al. 2012.

[23] It is faithfully reported what was written - on the occasion of a recent discussion on the use of SAR in historical centres - by Prof. Sandra Lucente, Researcher in Mathematical Analysis at the University of Bari "Aldo Moro". Source: Rubrica 404 Error., Questo non è un video mapping e quello non è Van Gogh; http://www.glowarp.com/5_questo_non_e_un_video_map

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10 DIGITAL MODELS FOR THE ANALYSIS AND COMMUNICATION OF PERSPECTIVE SPACE

LEONARDO BAGLIONI, MARTA SALVATORE

Abstract

Today, digital tools play a leading role in the knowledge, valorisation and communication of cultural heritage. Imagining to measure the heritage value in terms of knowledge and the growth of this value as flow of knowledge, one must consider cultural goods in the dual aspect, material and immaterial, that characterizes them. In some artistic fields, there is a close relationship between the artwork and the scientific theories that underlie it. Among these, a leading role must be given to perspective and its applications, in which realized works are the result of the application of projective theories handed down through centuries of history in historical treatises and texts. Knowledge of the work is therefore the result of the interaction between material and immaterial assets, whose awareness favours its conservation, promotes its valorisation and feeds its communication. The interest in perspective lies in its relevance, namely in the immutability that characterizes it in the history of representation. The projective principles on which it is based, in fact, range from graphic representation to the most recent forms of digital representation. Today it is possible to reconstruct in a parametric digital environment, the perspective machine in its most general form, solid perspective, of which the linear perspective is a special case. The parameterization of the projective procedures at the basis of perspective allows the dynamic exploration of the projective space, in its evolving and in its limit configurations, that are the real space and the linear perspective. The exploration of these models has a double purpose. It is a breeding ground for interesting suggestions for research, and at the same time it is an opportunity to make explicit and therefore accessible to a vast and heterogeneous public 'what is not visible', namely the theoretical principles on which the functioning of the perspective machine is based.

Gli strumenti digitali assumono oggi un ruolo di primo piano per la conoscenza, la valorizzazione e la comunicazione dei beni culturali. Se si immagina di misurare il valore del patrimonio in termini di conoscenza e l'accrescimento di questo valore in termini di flusso della conoscenza, bisogna considerare i beni culturali nel duplice aspetto, materiale e immateriale, che li caratterizza. In alcuni ambiti artistici sussiste una stretta relazione fra l'opera d'arte e le teorie scientifiche che ne sono alla base. Fra questi un ruolo di primo piano deve essere riconosciuto alla prospettiva e alle sue applicazioni, in cui l'opera realizzata è il risultato dell'applicazione di teorie proiettive tramandate in secoli di storia in trattati e testi storici. La conoscenza dell'opera è dunque il risultato della interazione di beni materiali e immateriali, la cui consapevolezza ne favorisce la conservazione, ne promuove la valorizzazione ne alimenta la comunicazione. L'interesse per la prospettiva risiede nella sua attualità, e cioè dalla immutabilità che la caratterizza nell'ambito della storia della rappresentazione. I principi proiettivi su cui questa si fonda ricorrono infatti dalla rappresentazione grafica alle più recenti forme di rappresentazione digitale. Oggi è possibile ricostruire in ambiente digitale parametrico la macchina prospettica nella sua forma più generale, quella della prospettiva solida, di cui la prospettiva lineare è un caso particolare. La parametrizzazione dei procedimenti proiettivi alla base della prospettiva permette l'esplorazione dinamica dello spazio proiettivo, nel suo divenire e nelle sue configurazioni limite, lo spazio reale e la prospettiva lineare. L'esplorazione di questi modelli ha una duplice finalità. Foriera di interessanti spunti di ricerca, si configura allo stesso tempo come l'occasione per esplicitare e perciò rendere accessibile ad un pubblico vasto ed eterogeneo ciò che non è visibile, e cioè i principi teorici su cui il funzionamento della macchina prospettica si fonda.

Introduction

The elaboration of digital strategies for knowledge, valorisation and communication of cultural heritage is today a central issue, which affects in a transversal way different areas of research and which concerns different types of assets. When one thinks about cultural heritage, he intuitively imagines a tangible asset, such as a monument or an emergency of historical value. However, the idea of a cultural asset goes beyond its material meaning to extend to immaterial assets which, like the others, have acquired a certain historical value over time. According to this broad meaning, in which the value of an asset becomes measurable in terms of knowledge, we can consider as cultural assets the theoretical contents of treatises and historical texts, evidence of the state of knowledge in a given era and vehicle of its dissemination[1].

In some artistic fields there is a close relationship between the artwork and the scientific theories that underlie its realization. Among these, a leading role must be given to perspective and its applications in the arts. Renaissance and Baroque architectural perspectives, for example, are undoubtedly material cultural asset, because they are recognised historical value artworks. Equally important, however, is the process used for their realization, handed down through the pages of the many treatises on perspective written in those years. The understanding of the work is therefore the result of the interaction of material and immaterial assets, whose full awareness favours its conservation, promotes its valorisation and feeds its communication.

The interest in perspective is due to the immutability of its theoretical assumptions, which are at the basis of all forms of realistic representation of reality, today as in the past. In fact, able to simulate the human vision, perspective recurs in different ways in the applied arts, since its first forms of expression of the Roman era. During the Renaissance, with the codification of the method, it was declined in different forms in the applied arts, reaching an expressive peak in the spectacularity of the mathematical *ludi* of the Baroque era. The research of realism in the representation of reality led some eighteenth-century painters to the use optical cameras, based on the same projective principles at the basis of perspective, which would soon transform it into photography. The construction of digital images from three-dimensional models is also the result of the application of the same principles, as demonstrate the most recent applications of virtual and augmented reality, that operate in the field of the vision, interacting with perceived space and altering its perception.

The transversal character of perspective, which permeates the history of representation up to its most recent forms of digital representation, has animated this experimentation, which aims to explain, through the construction of dynamic parametric digital models, the functioning of the perspective machine in its theoretical and applicative aspects. The objective is twofold: exploring the projective space from the inside and from the outside for the purpose of analysis and study of perspective; making the theoretical foundations accessible to a wide public in a simple and direct way, involving the observer in an immersive experience within the perspective representation with which relating and interacting.

Digital exploration of projective space

When one imagines a perspective, he generally refers to a two-dimensional image that represents the space 'as it looks'[2] to the eyes of an observer. However, perspective has a broader meaning than this. If we imagine replacing the plane of the painting with a portion of space, we can see how the perspective image loses its two-dimensional character and how the represented objects appear deformed in this three-dimensional space, in a more or less accentuated way. The space in question is called *projective space*, and it is the place where *solid perspective* takes place,

Fig. 1 - Solid perspective of the choir of Saint Mary near Saint Satyrus in Milan realized by Donato Bramante in 1482-1486 (photo by authors)

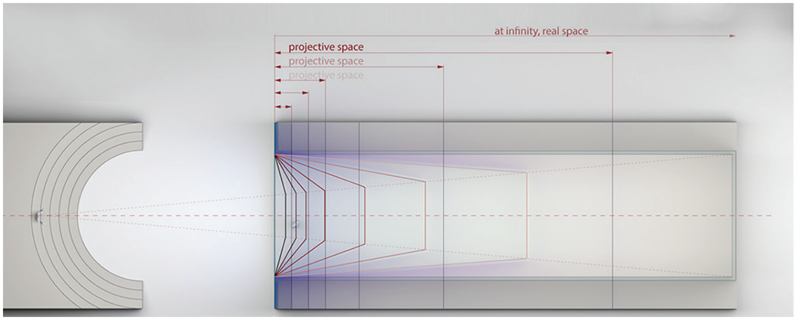
of which linear perspective is a special case. Therefore, the extension of the projective space varies between two limit conditions: the affine space, which corresponds to reality ‘as it is’ and expresses its condition of maximum dilation, and the linear perspective, which instead represents its maximum contraction.

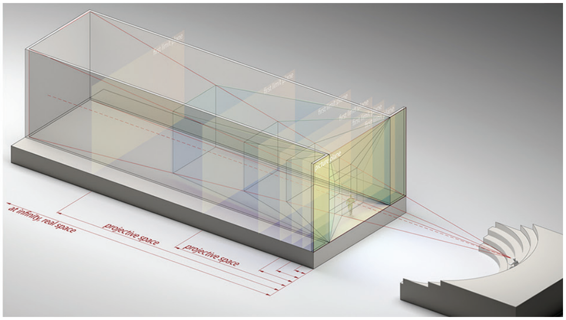
There are not many solid perspectives that have reached us and, in general, the studies conducted on them concern a single and specific phase of the process of projective transformation, which corresponds to the work in question. The study of the projective transformations of the space requires, in order to be investigated in its becoming, a dynamic and immersive exploration. This exploration should be performed from inside, making the operator an integral part of the perspective machine, capable of appreciating its perceptual effects. At the same time, it should be performed from the outside, allowing the observer to understand its reasons and to appreciate its functioning.

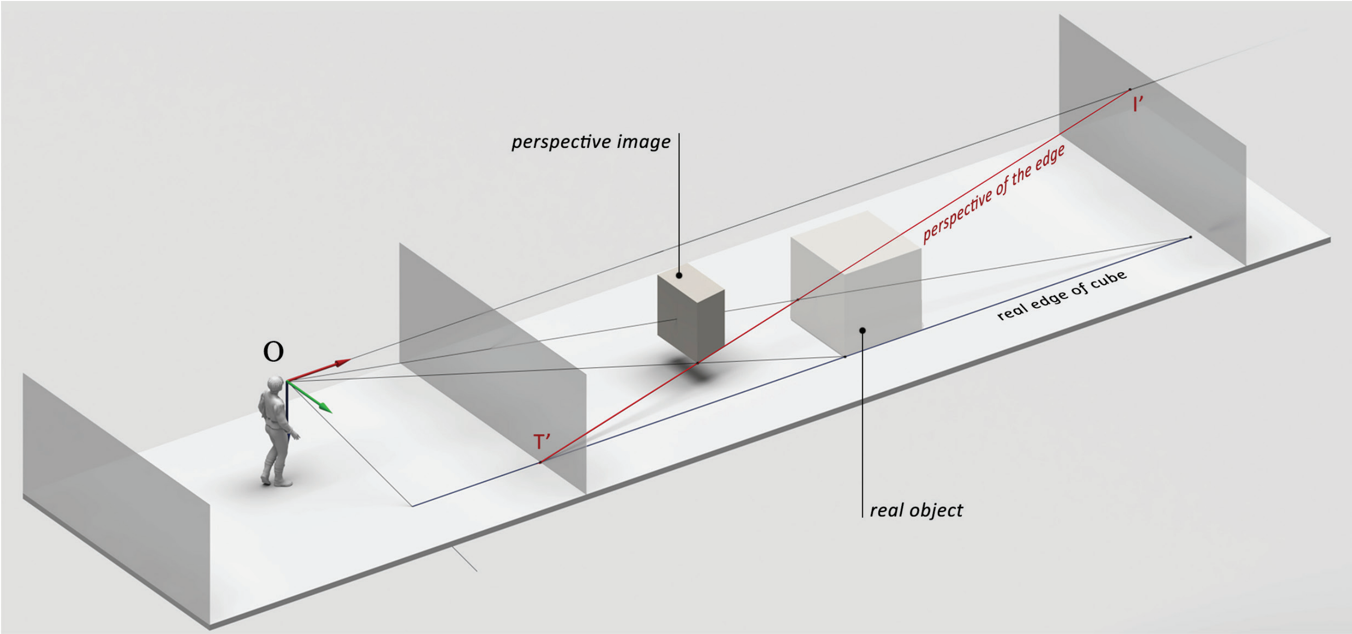
Today it is possible to reconstruct in a digital environment and in a parametric language the projective space, reproducing in a dynamic way the perspective machine, understood in its most general meaning, i.e. in its solid form[3]. In fact, in a solid perspective the picture plane is replaced by a portion of space, delimited by two planes, which respectively receive the traces and the vanishing points of the represented objects[4]. The separation and the approach of these two planes causes the dilation and the compression of the projective space, which reaches its limit conditions in the two cases already described: the affine space, which occurs when the plane containing the vanishing points reaches the infinity[5] and the linear perspective, in which the two mentioned planes coincide, and the projective space is therefore reduced to a plane.

A perspective machine conceived in this way allows us to explore all forms of exact representation of reality, where by *exact* we mean a form of representation derived from projection and section operations of the real environment, in order to obtain a two-way correspondence between reality and the infinite images that can be generated. The possibility of reproducing all the phases of the projective transformation process of the space and interacting with them, is the source of various opportunities for research. These include the possibility of investigating the vision in a dynamic perspective space and measuring how the contraction and expansion of perspective space influence its perception.

Thus, the effectiveness of the reproduced perspective machine has been tested in the case of particular illusory spaces, involving many perspective artists between the sixteenth and seventeenth centuries: those of the theatrical scenography which, in those years, responded in general to the perspective laws[6]. In particular, the model of an ideal theatrical scenography was reproduced, inspired by







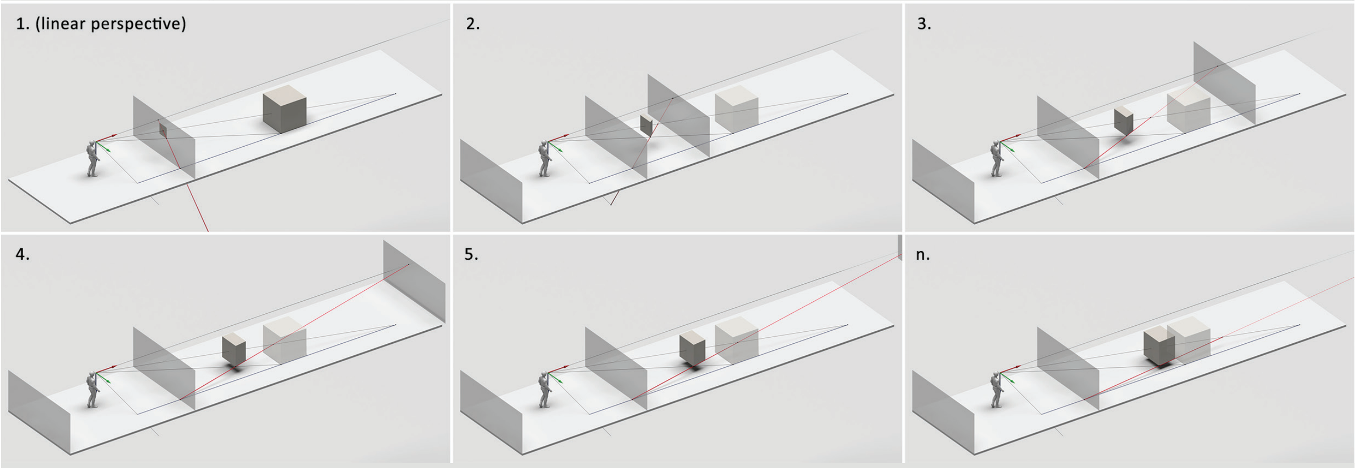
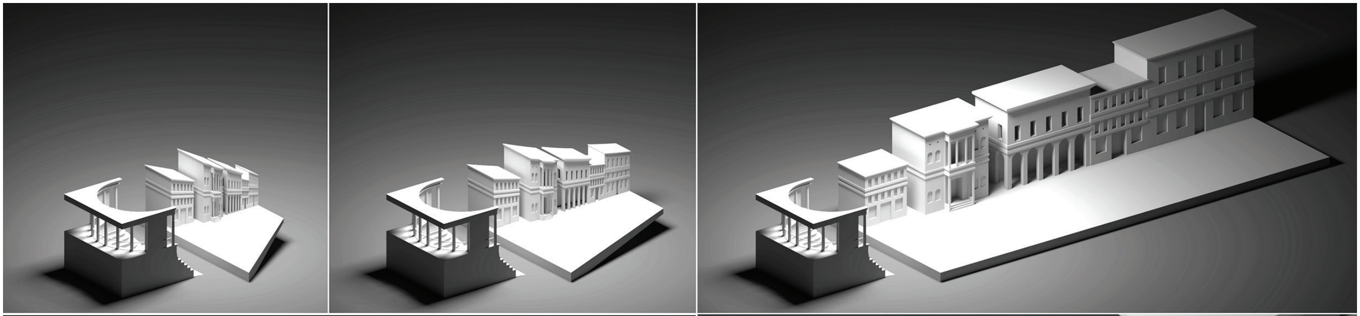


Fig. 2 - Projective transformations of a cube within the perspective machine

Fig. 3 - Phases of the process of projective transformations of a Renaissance scenographic system



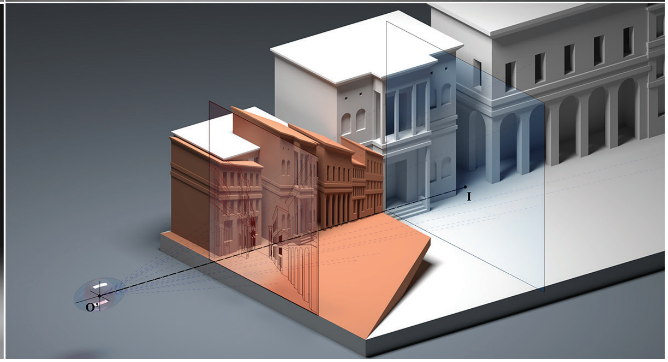
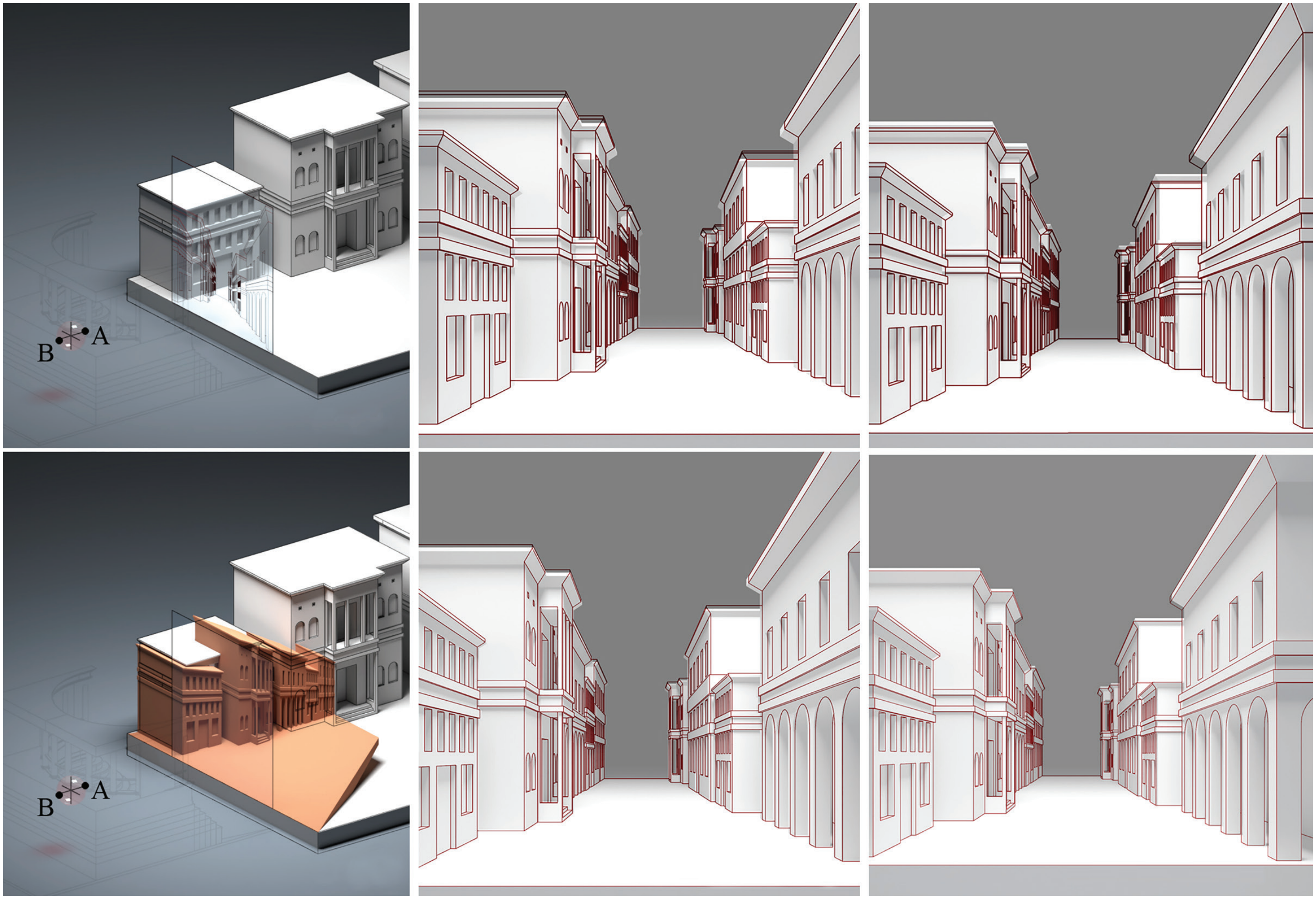


Fig. 4 - Dynamic exploration of the scenic space applied to the ideal model of a Renaissance scenography inspired by Vincenzo Scamozzi's drawings for the theatre of Sabbioneta

Fig. 5 - Investigation around the limits of the restricted sight and effects of solid perspective with respect to linear perspective.

the sixteenth-century drawings of a project designed by Vincenzo Scamozzi for the Sabbioneta theatre. The sets of the Renaissance court theatre can be considered among the first applications of solid perspective, although the contraction of perspective is limited to the space of the box stage. The possibility of varying the level of contraction of the scene and consequently the level of contraction of the buildings represented on it, has made it possible to investigate the vision in a more or less broad around of the *veduta vincolata* (restricted sight). For each of the observation positions chosen, the effects of the expansion and compression of the space were measured. This kind of analysis, possible only through the dynamic observation of the projective transformations in question, has shown how the solid perspective extends the limits of the restricted sight, intervening as a sort of accelerator capable of reducing the apparent deformations of the perspective image[7]. The dynamic use of the space has oriented a second phase of experimentation towards the study of vision outside the restricted sight, in different conditions of expansion and contraction of the scene. This second analysis has shown how the illusory power of perspective persists in the theatre well outside of the restricted sight. Perspective restitutions of the spaces that are formed in

the different phases of the contraction of the scene, seen from different points of the audience, allude to as many real spaces, different from each other, but all geometrically verisimilar.
The main purpose of the realized parametric model of the perspective machine concerns the study and validation of some theories that investigate the functioning and effects of perspective, such as those mentioned above. However, there is a second purpose, no less noble than the first, which sees these virtual models as an opportunity to illustrate in a simple and direct way, to a vast and inexperienced public, the functioning of the perspective machine.
The dynamic perspective machine thus expresses the close relationship that exists between a perspective artwork and the generative principle according to which it was realized. This close relationship, evident in all the phases of



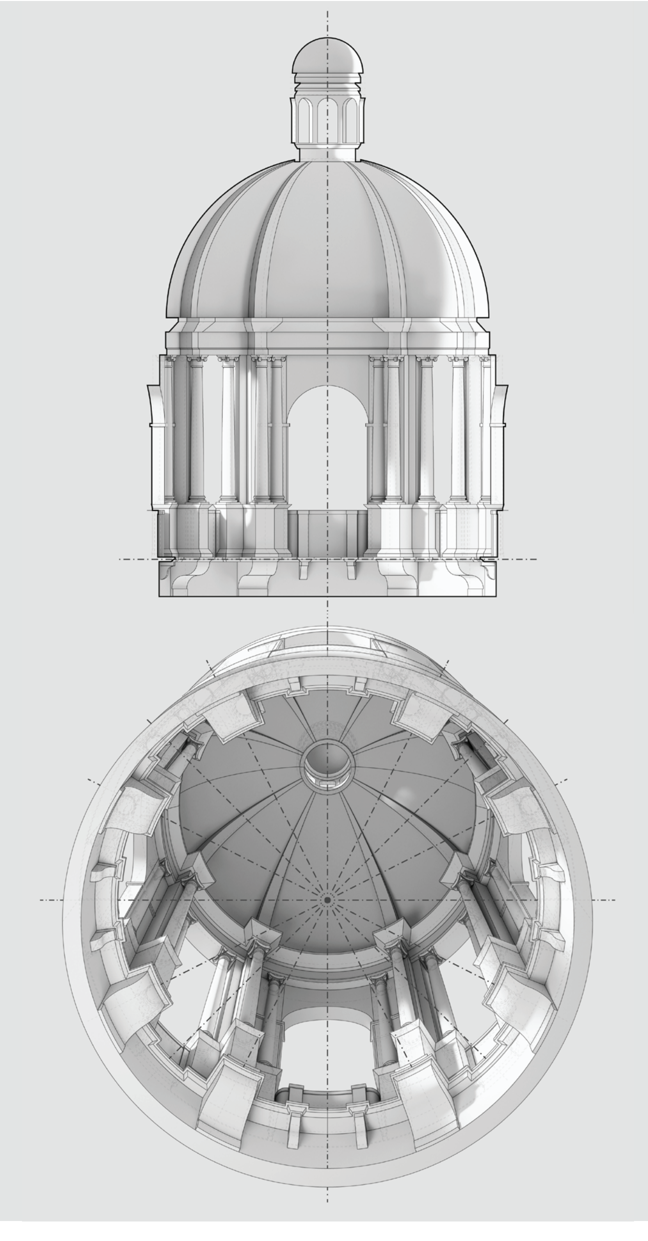
the process, is revealed in the analysis of the relationship between the two boundary configurations of the projective space: the affine space and the linear perspective.

Digital exploration at the extremes of projective space

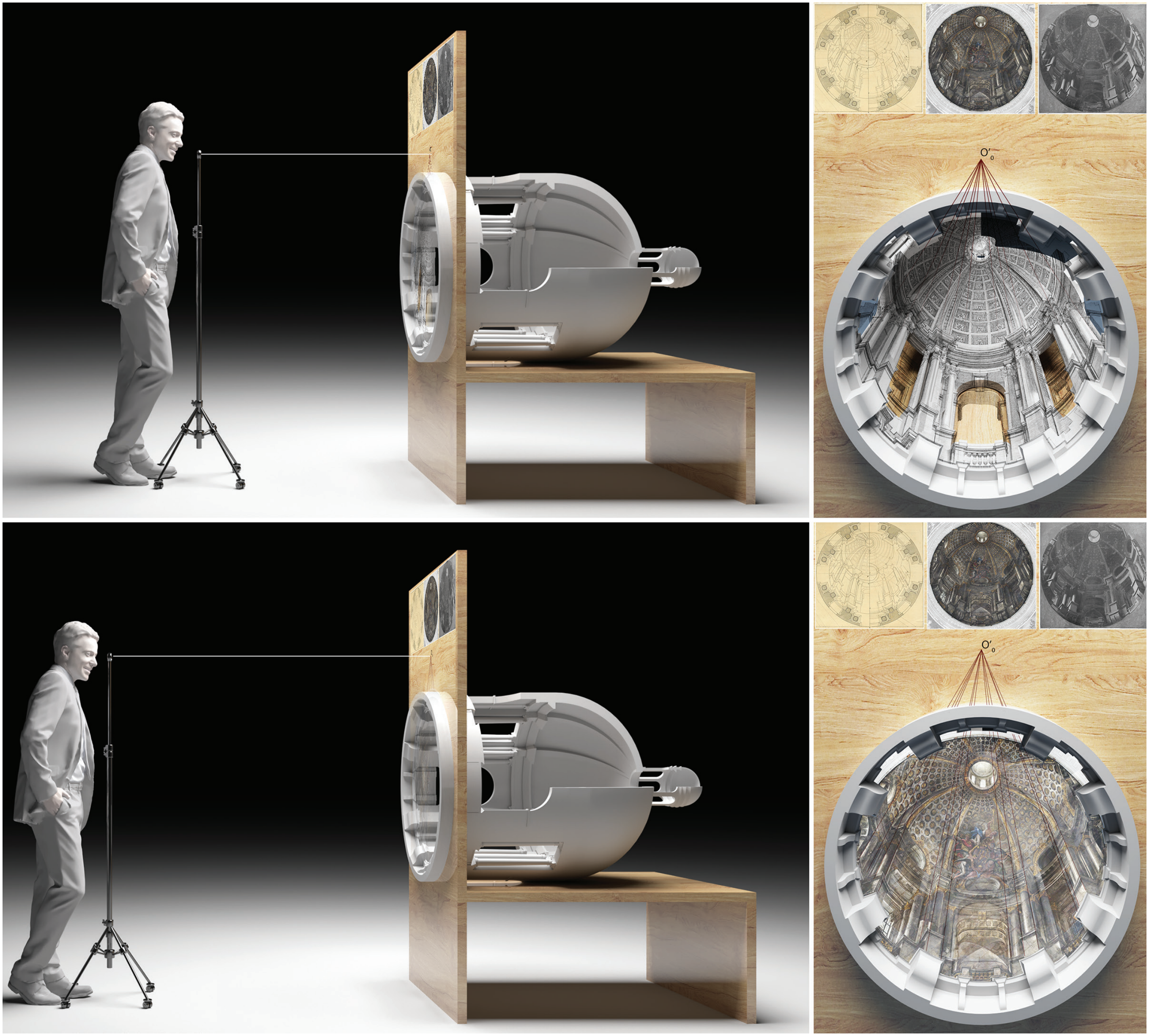
The projective space moves without interruption in an extension that varies between the two limit configurations mentioned above: the real space and the two-dimensional graphic space of the linear perspective.
This second experimentation concerns the analysis of the relationship between the boundary conditions of the projective space and the communication of these relationships through the materialization of the digital model reproduced in physical form with techniques of rapid prototyping. If the digital model constitutes an interactive platform through which studying the projective relations that exist in a perspective, the prototyped model becomes the place of the experimental validation of such theories, but at the same time a precious vehicle capable of making explicit and accessible the theoretical contents.
For this purpose, Andrea Pozzo’s theoretical and practical work is particularly significant. The interest in this author is to be found in the dual character of his activity, on the one hand theoretical, as demonstrated by the contents of his treatise *Perspectiva pictorum et architectorum* (1693-1698), on the other hand applicative as evidenced by the countless architectural works, painted and real, come down to us. Studying the relationships that exist between the theoretical models of the treatise and those realized means, as already introduced, to investigate the concept of cultural asset in its material and immaterial connotation, extending its meaning to the knowledge of the theoretical contents, often inaccessible, on which it is based.
The experience presented is the result of research conducted on the fake dome painted in the church of Saint Ignatius in Rome in 1685 and still visible despite the turbulent events that has been involved. It is a circular

Fig. 6 - The perspective models of the fake dome of Saint Ignatius: the canvas, the sketch and the treatise

Fig. 7 - The mathematical model of the dome



canvas of about 16 meters in diameter on which is painted a dome set on a tambour with cantilevered columns resting on shelves that, viewed from the right position, generates in the viewer an illusion that extends the real space by means of the perspective with which it appears in continuity. The canvas of Saint Ignatius corresponds to three different models of perspective: the preparatory sketch, the painted canvas and the engravings of the treatise that describe the procedure used for its realization. These three models represent three distinct perspective images of the same architectural subject. The main objective of the experiment is to demonstrate the existence of a single ideal model of the dome, of which the perspective models are images, through the materialization of the projective relationships that are established between the observer, perspective and ideal architecture. The investigation of the relationship between the true form and the different perspective images that it produces, has been investigated through the reconstruction of a digital model of the dome.
The true shape of the dome is the result of a scientific and therefore repeatable process that has retraced backwards the different phases of generation of the architectural perspective comparing it with the project drawings published in the treatise. This procedure, known as *inverse problem of perspective*, is not easy to solve in the case of perspectives ‘from below’ because in these images the picture plane is horizontal and therefore parallel to many architectural elements that are generally used as a reference for the identification of significant points of perspective (points of distance, main distance, etc.). The restitution of the true shape of the dome has been possible by verifying some relations of invariance that are at the basis of the cross-ratio in perspective[8]. The verification of this invariance has been calculated for each of the witnesses and has analytically demonstrated a common matrix in the proportioning of the architectural order represented in the different perspectives and in the drawings of the treatise. By means of these analyses it was possible to determine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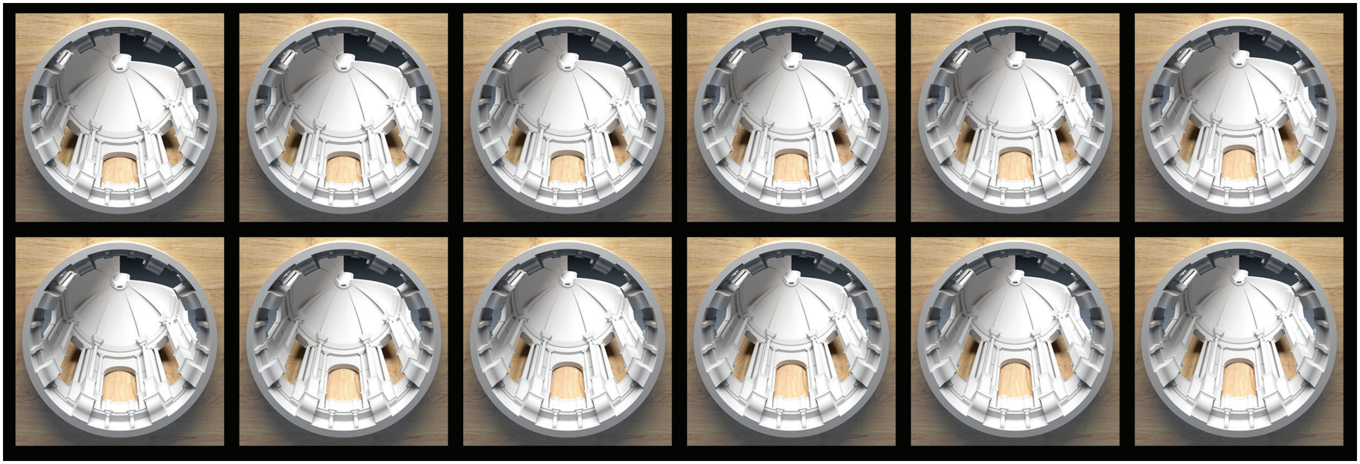

Fig. 8 - The project of the installation with the prototyped model

Fig. 9 - Contraction and expansion of the depth of the projective space related to the distance of the observer from the picture plane

the position of the projection centre for each of the models analysed, unambiguously determining the restitution of the perspectives.
The construction of the model was obtained with a continuous description of shapes, the only one able to guarantee perfect coherence with the projective logics that the model itself intends to describe. The model, which as a whole relates the dome to the different perspective images that correspond to it, has experimentally validates the initial hypothesis. Its communicative potential finds its maximum effectiveness when it acquires physical form, in the passage from the virtual world to the real one. The prototyping of a digital model, if properly controlled in its different phases of generation[9], guarantees the preservation of the intrinsic qualities and geometric properties of the form, an aspect of fundamental importance for the experimental purposes of these studies. The construction of the physical model, making tangible the two boundary configurations of the projective space, allows an inexperienced observer to experimentally verify the congruence between the real model and the different graphic models that correspond to it.
In fact, the prototype was installed on a vertical plane and positioned at the height of the plane of the impost of the dome to which corresponds the picture plane. The installation provides for the possibility of inserting three transparent discs in the picture plane on which the different perspectives of the fake dome are represented in the cited models (that of the treatise, the sketch and the canvas) each one associated with its main distance to ensure the exact location of the relative projection centres. The installation can be exploited in two different ways: from the inside, as an *observer*, and from the outside, as a *spectator*. In a restricted sight position, as an observer, it is possible to experimentally verify the theory that the perspectives of the fake dome of St. Ignatius are different images of a single ideal architectural model and at the same time to intuitively appreciate the depth of the

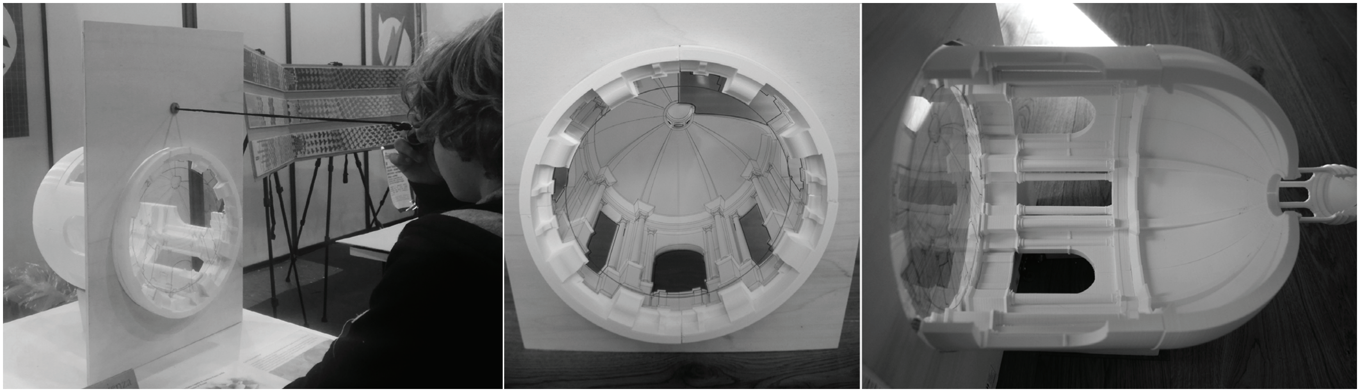

Fig. 10 - Presentation of the model at the Maker Fair 2018 in Rome

projective space, which seems to contract and expand as a result of an observation of the real model more or less close to the picture plane. As a spectator, it is possible to observe the functioning of the perspective machine from the outside, and to fully appreciate the projective principles at the base of the design process undertaken by Pozzo. The described installation was recently presented at the Maker Fair in Rome (October 2018) to a heterogeneous and rather vast public, arousing great curiosity and amazement, confirming once again the ability to surprise, characteristic of the illusory power of perspective.

Conclusion

The presented experiences were structured and addressed according to a dual value, experimental and communicative. The digital models created, whether in virtual parametric form or in physical form, have been developed in a virtual laboratory in which experiments of analysis and investigation of the projective nature of the cases studied have been conducted. These experiments have shown how the digital model understood in its most general sense, in its various forms of static and dynamic representation, is a particularly effective tool for critical analysis, knowledge and communication of cultural heritage, material and immaterial.

The main objective of these studies is to bring out 'what is not visible', thus making it accessible to a wide and heterogeneous public. This *modus operandi* is intended to revisit the idea of accessibility of a cultural asset. Generally understood as overcoming a physical limit to the fruition of an asset, the concept of accessibility extends to the fruition of the theoretical contents related to that asset. Accessibility therefore conveys the flow of knowledge contributing to feed the value of the cultural asset.

Notes

[1] The concept of the value of a cultural asset is a debated and complex issue that can take on different meanings at the same time. In this study, the value of a cultural asset must be understood as a cultural value, capable of generating other cultural values, transmitting information, building meanings, stimulating the sense of sharing values, in a continuous process in time and space. Cf. Di Matteo 2008, pp. 375-382.

[2] The definition 'space as it is' by which we mean real space is inspired by Rudolph Arnheim's studies on the vision in which an object is perceived 'as it is' and 'as it looks'. Cf. Arnheim 1981, pp. 128-163.

[3] Cf. Migliari 2005, pp. 133-160.

[4] Cf. Migliari, Romor, Salvatore 2014, pp. 39-47.

[5] For this reason, according to some studies conducted in the Nineteenth century by Otto Wilhelm Fiedler, all representation methods can be traced back to solid perspective.

[6] Cf. Baglioni, Salvatore 2017, pp. 1-12.

[7] The expansion of the projective space corresponds to the widening of the boundaries of the restricted sight, which instead assumes its minimum dimensions in the case of linear perspective.

[8] The cross-ratio is the ratio of the simple ratios between the lengths of three aligned segments that remains unchanged after one or more projection operations. Given the three segments AB, BC and CD the cross-ratio is (AC/BC)/(AD/BD).

[9] The conversion of the digital continuous model to a discrete one has been carried out ensuring maximum morphological consistency, entrusting the logic of discretization to the control of the curvature parameter.

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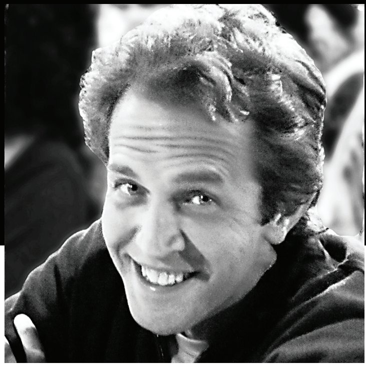

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11 FOOD AND WINE HERITAGE IN THE MARCHE REGION: DIGITAL STORYTELLING THROUGH VIRTUAL AND AUGMENTED REALITY

Daniele Rossi, Federico Orfeo Oppedisano, Carlo Vinti

Abstract

The local wine and food heritage is a crucial element of the identity of a territory and often becomes a crucial theme in tourism promotion. Typical food and wine products are used both to develop branding strategies aimed at redefining the image of a territory and to launch initiatives in the field of experiential tourism. However, so far there are not many projects that explore the potential of Virtual Reality (VR) and Augmented Reality (AR) technologies in this field. Recently, the rapid development of devices that allow the use of Mixed Reality (VR and AR) has made these technologies - which have been known for decades but have always been relegated to the experimental field of technological and media research - very topical. This article aims to summarize the assumptions of an interdisciplinary research concerning the enhancement and storytelling of the wine and food heritage through applications built on technologies of Mixed Reality.
The purpose of the research is twofold: to investigate, in general, what are the potential of VR and AR to enhance and promote the richness of the territory in terms of wine and food heritage; experiment with new design strategies and new forms of communication through the use of cutting edge technology, in particular, in the case of the Marche Region.

Il patrimonio enogastronomico locale costituisce un elemento cruciale dell'identità di un territorio e diventa spesso un indispensabile strumento di promozione e di attrazione turistica. I prodotti enogastronomici tipici sono usati sia per mettere a punto strategie di branding volte a ridefinire l'immagine di un territorio sia per iniziative nel settore del turismo esperienziale. Tuttavia finora non sono molti in questo campo i progetti che esplorano le potenzialità delle tecnologie di Realtà Virtuale (VR) e Aumentata (AR), particolarmente adatte a valorizzare tale patrimonio in una chiave esperienziale. Il rapido e recente sviluppo di dispositivi che consentono la fruizione di Mixed Reality ha reso di grande attualità queste tecnologie note da decenni ma da sempre relegate all'ambito sperimentale della ricerca tecnologica e mediatica. Questo articolo intende illustrare presupposti e obiettivi di un progetto di ricerca interdisciplinare centrato sulla narrazione per la valorizzazione del patrimonio enogastronomico attraverso tecnologie innovative per la mixed reality, fruita sia tramite visori binoculari sia tramite la mediazione di un dispositivo (tablet, monitor, ecc.).
Lo scopo della ricerca è duplice: indagare, in generale, quali sono le potenzialità di VR e AR per valorizzare e promuovere la ricchezza del territorio in termini di patrimonio enogastronomico; sperimentare nuove strategie di progettazione e nuove forme di comunicazione attraverso l'utilizzo di tecnologie innovative, in particolare, nel caso della Regione Marche.

Introduction - Concept and objectives

In recent years the importance of gastronomic tourism has been steadily increasing, both in terms of demand and supply, resulting in the development of large tourist areas that have managed to endorse territorial value relying on the quality of typical productions, culinary traditions, the rural landscape, the quality of the environment and, more generally, on a wide range of other intangible natural attractions[1].

In a vision of cultural heritage which is not limited to buildings and statues, food and wine are part of intangible heritage: a set of rich traditions in societies that are passed down the generations and are certainly no less important to preserve for the future.

Typical food and wine products, intended as part of a socio-cultural system, constitute a key-element of the local cultural heritage as well as a crucial factor for the development and promotion of places and regions. This project focus on the enhancement and storytelling of food and wine heritage, intended as essential components of a "territorial capital".

The new challenge of tourism today is to imagine new strategies of preservation and fruition, and, above all, approaches to management that place the local community at the centre, and which, at the same time, activate the visitor, placing him in harmony with the context: with the history of the place and its food and wine traditions. Interest in food is often strictly linked to, and associated with, its history, which bestows on it a unique value and contributes to creating an excellent quality product. The focus of this article - which summarizes the assumptions of a newly started interdisciplinary research at the School of Architecture and Design of the University of Camerino - is therefore on the idea of "experience", going beyond a pure valorisation for tourism purposes, in order to encourage the creation of new forms of communication of the wine and food heritage through applications built on technologies of Mixed Reality[2].

The research aims in particular at providing technologically innovative instruments based on mixed reality systems in order to tell and disseminate food and beverage traditions of the Marche region and their history.

The systems and applications that are intended to be developed through research are aimed at increasing the visitor's interest in food and environmental education by enhancing not only local products but also the places of origin and the production chains typical of Marche wine and food.

Therefore, the research aims to design innovative food and wine itineraries, able to guide users towards the knowledge of local food and wine excellences such as: *olive all'ascolana, mela rosa dei Sibillini, miele dei monti azzurri, formaggi di Fossa, salame di Fabriano, pecora sopravvissana, ciuascolo dell'alta marca, crescia fogliata di Fiuminata, torrone di Camerino, salame di fichi marchigiano, verdicchio di Matelica, Vernaccia di Serrapetrona, vino cotto di Loro Piceno, pesca della Valdaso, pesce dell'adriatico, vincisgrassi, carciofo di Monte Lupone* and so on.

Visual design for the enhancement of the territory

Typical regional food and wine products are not to be intended as mere food or beverage. As several studies have shown, food and wine products are the result of a local socio-economic system, made of natural and cultural resources[3]. This is particularly true in agricultural districts such as those of the Marche region, where the excellence of the products is based on a mix of quality of production (local manufacturing and culinary traditions), quality of the territory and landscape (cultural heritage, environmental protection, etc.) and quality of life (human relations, well-being, etc.). For these reasons, typical regional products have a rich story to tell in terms of territorial capital: namely, as the product of a territorial system made of economic, cultural, social and environmental assets[4].

Fig. 1 - Mario Giacomelli, photography from the series *Storie di terra - presa di coscienza sulla natura.*

Fig. 2 - Tullio Pericoli, *Senza titolo*, 2016.

A territorial capital is a complex set of different material and immaterial components: physical resources (architectural and artistic heritage, environmental heritage), culture and identity (mentality, shared values and traditions) as well as human resources, know-how and skills (companies and local production activities)[5]. Food and wine products play a crucial role in building a territorial capital: they are fundamental elements of the territorial identity, often becoming an indispensable promotional mean and a tourist attractor. As such they can even brand an entire region, as the cases of Barolo/Langhe, Franciacorta or Chianti show. Local products are often the focus of specific branding strategies aimed at redefining the image of territories[6] and are increasingly at the centre of activities focused on experiential tourism. However, so far only very few of such projects and initiatives have explored the potential of VR and AR technologies in improving, enhancing and amplifying the experiential dimension (immersive, multimedia and multisensory).

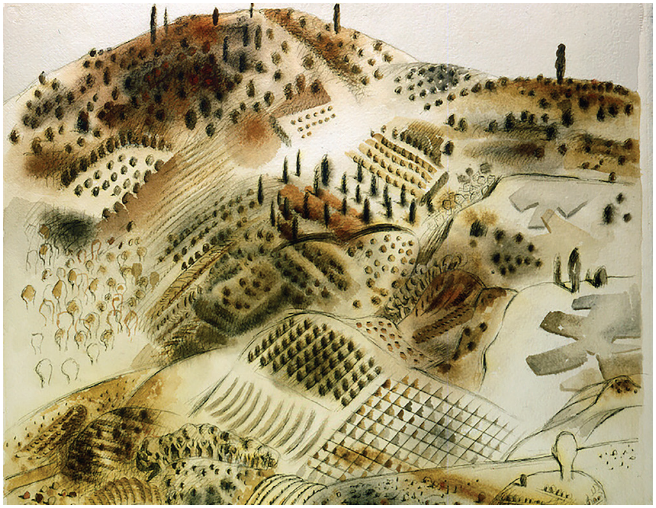
In recent years, research by design in Italy has often focused on the enhancement and communication of territories. Since the 1980s, several projects have been

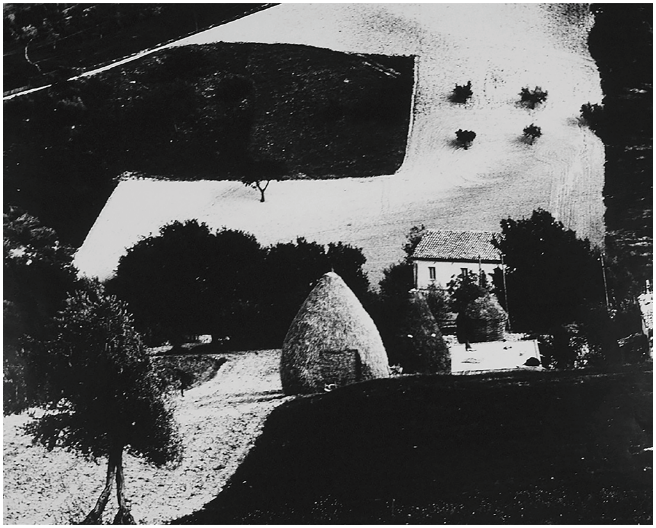
Fig. 3 - Mario Giacomelli, photography from the series *Storie di terra - presa di coscienza sulla natura.*

Fig. 4 - Tullio Pericoli, *Terre rosse*, 2007.

Fig. 5 - Mario Giacomelli, photography from the series *Storie di terra - presa di coscienza sulla natura.*

Fig. 6 - Tullio Pericoli, *Paesaggio instabile*, 1998.





based on design as a methodological tool able to enhance, tell and innovate the local cultural heritage, both material and immaterial[7]. These projects have shown that design can be an important driving force for innovation and the economic and social development of territories, but also to support and stimulate the ability of local communities to discover and recognize potential territorial assets and transform them into real resources[8].

In design-driven processes aimed at the enhancement of territories, visual design can play a crucial role especially for the creation of narrative strategies. Narrative tools can be employed at different stages: from the analytical and exploratory phase to the definition and implementation of different actions and interventions. In the specific context of this project, visual design will contribute to positioning the use of VR and AR technologies in the context of a broader storytelling strategy based on experiential activities like, for example, the exploration of local itineraries for discovering food and wine quality products (when, where and how they are produced and consumed).

VR and AR technologies: context, definitions and state of the art.

When, in the mid-1970s, Myron Krueger[9] coined the term Artificial Reality, his goal was to define a kind of digital experience so immersive that he could be perceived as real. He used the concept of Artificial Reality as a tool for examining man-machine relations, analysing possible exchange interfaces, and examining the socio-cultural relations associated with it.

In the early 1990s, the idea of Artificial Reality was overtaken by the concept of Reality-Virtuality continuum, graphically synthesized by Paul Milgram[10]: in a horizontal segment where he pointed to the two extremes the Real and Virtual, and in the range of the two, a Mixed Reality type that blurs in Augmented Reality or Augmented Virtuality depending on the names that can be traced in literature. Milgram then used this definition to construct a taxonomy of visual systems for environments in Mixed Reality depending on the degree of immersion required and the immersion device.

If the user has experience of a reality where what is actually existing around if we are adding structured digital information we are in the field of Augmented Reality, or that field of computer graphics that investigates the possibility of superimposing the perceived reality of digital elaborations. Vice versa if the user has experience of a completely artificially digital reality where digital information is structured to conform the perceived world then we are in what Jaron Lanier in the early 1980s had called Virtual Reality[11].

To date, virtual reality, augmented reality, mixed reality, haptic feedback, gesture recognition, etc., are technologies that tend to become more and more confused with each other and can be grouped just under the the general term of Artificial Reality, thus achieving Krueger's predictions.

With the launch of Google Cardboard and the crowdfunding campaign to fund the Oculus Rift project suddenly, in the early '10s of the new millennium, the commercial interest for a sector that remained for too long was the subject of interest for a few research centres or for sci-fi cinemas.

Fig. 7 - Mario Giacomelli, photography from the series *Storie di terra - presa di coscienza sulla natura.*

At first Google with its Glass has attempted new pioneering ways in the reality field, and then quickly released the first virtual reality viewers by the Oculus Rift team followed by HTC with the Vive that uses the Steam distribution platform, and the Playstation VR, which has definitively attacked the home gaming console market.

In addition to these complete HMD viewers, some less expensive alternatives involve the use of smartphones and tablets to integrate apps and mobile solutions through "adapters" such as Samsung Gear or Google Daydream.

On the other hand, augmented reality as well as other technologies of military origin (GPS navigators, the first mobile phones, drones) have already been used in industry since the 1960s. It can therefore be said that the AR applications, more than VR applications are used in the production, logistics and distribution phases. By means of AR headset, for example, two people can discuss a problem in real time by observing the subject of the problem, without being in the same place. In the same way, an employee can be assisted in every operation by a series

Fig. 8 - Tullio Pericoli, *Paesaggio instabile*, 1998

of instructions projected on his AR viewer. He can operate safely and supervised by more experienced colleagues.
Indeed, from the point of view of the consumer most of the apps we use every day will be enhanced by AR. In this case there will be no need for additional devices because all that is needed is one of the most widespread communication tools in the world: the smartphone. In this regard, just think about the investments made by two of the major players in the IT industry: Google, through the ARcore platform for Android, and Apple with ARkit. Furthermore, Microsoft is ready for Hololens' worldwide launch that will make promises made and temporarily abandoned by Google Glass technology.

Methodology and objectives

Digital technologies have radically changed the approach to knowledge by transforming cultural and heritage sites into interactive, interconnected and multimedia environments, enabling you to explore, learn, share, and deepen in an exciting way. In the same way, technologies born and used for areas related to gaming and entertainment can help in the valorisation and promotion of an entire territory characterized by a specific agri-food ecosystem.
The research project discussed in this article aims to be a pilot experiment in the use of VR and AR technologies for the enhancement of the territory as a whole and not of a single artefact. In particular, the goal is improving the Marche region and its excellence in the agri-food and food-and-wine sector, providing historical/cultural information through digital 3D applications directed to a wider public composed of broadcasting audience, network users, tourists, scholars as well students and teachers of high schools and universities.
One of the challenges identified by the *Regional Smart Specialization Strategy*[12] is to increase the diffusion of ICT in the productive business fabric.
Among the main purposes of this Strategy is the promotion of the transition from the current district system towards a new industrial organization able to support traditional productive vocations with a qualitative improvement and a technological upgrade.
The project development strategy is therefore aimed at revitalizing the productive fabric of the Marche through the focus on certain advanced technological fields such as Domotics, (Design & Virtual Simulation and Prototyping) and ICT understood as transversal enabling technology.
In order to build a theorical and methodological framework the research project will follow three distinct phases:
In a first phase a study on the state of the art will be carried out to identify, in agreement with the stakeholders of the territory, some case studies on which to develop the experiments. Particular attention will be paid to case studies from different food and wine sectors belonging to different geographical areas (inland and coastal areas). The completion of this phase will lead to a series of methodological indications useful for the definition of a first methodological-experimental idea.
In the second phase, a series of narrative data will be collected, and analyses will be carried out on the case studies identified, with the aim of constructing a database populated by cultural, historical and artistic information. This database will be the basis of a multimedia archive from which to draw all the data to be disseminated and shared in the third and final phase of setting up applications in virtual reality and augmented reality.
The third and last phase will be dedicated to the implementation, processing and validation of VR and AR applications in accordance with the indications and contents coming from the two previous project phases.
In order to elaborate virtual reality and augmented reality experiences, these applications will be examined by means of different verification methods, evaluating their performance and development prospects and testing them on expert and inexperienced users, as well as operators in the food and wine sector. Operators who will have the

task of testing the potential of these applications both for tourist-promotional and productive purposes.

Conclusions

Digital mediation techniques, three-dimensional models, 360 panoramas, dynamic interfaces, redefined spaces and times of learning. Indeed, it is indisputable that today the "new" media are the protagonists of a "shift" towards renewed communication models that aim to an extension of the cultural offer in an increasingly rapid and immediate form. The communicative actions and the new forms of representation aim to facilitate understanding, to clarify aspects of complexity, to present concepts in a clearer and more concise manner, to make the information more explicit and useful, while at the same time ensuring a high level of scientific content.
The above discussed research project – which is now in its early stages of development - will narrate the peculiarities of the Marche landscape in terms of food and wine heritage, through devices and applications with different levels of immersion. In recent years the opportunity to enjoy immersive experiences, but also non-immersive, virtual reality or augmented reality, has expanded to the extent of being considered within the reach of all.
Furthermore, VR experiences in the tourism sector nowadays seems to offer mostly marketing solutions for the promotion, with the aim of generating a favourable disposition towards the destination in the users. Mixed reality technology therefore appears to be a powerful tool for enriching and innovating the traditional ways of promoting a territory on the web (web sites, mobile apps, social media, ...). In this framework, the research project described in this article is intended to provide technologically innovative instruments based on mixed reality systems to tell and disseminate the variety of the food and beverage industry and its history linked to the territory of origin[13].

Note

[1] Cf. Bellencin, Meneghel 1991; Antonioli, Corigliano 2004; Montanari, 2008; Pioletti 2015.

[2] The research project presented in this article and called "*Food and Wine Heritage in the Marche Region: Digital Storytelling Through Virtual and Augmented Reality*" is financed with funds from the University of Camerino (FAR, Fondo d'Ateeo per la Ricerca) through a comparative evaluation procedure carried out by double blind reviewers.

[3] Cf. Graziani, Rizzi 2015; Allaire et al. 2011; Marsden 2013; Symbola 2015; Azadi et al. 2011; Marsden, Sonnino 2012.

[4] Cf. OECD 2001; Camagni, Capello2013.

[5] Cf. Simonelli, Zurlo 2004.

[6] Cf. Anholt 2007; Dioli, Rizzi 2010; Morgan et al. 2007.

[7] Cf. among the most recent Cf. Piccinno, Triunveri 2004; Marano 2004; Trapani 2004; Castelli, Vignati, Villari 2005; Cristallo, Guida, Morone, Parente 2006; De Giorgi, Germak 2006; Campagnaro, Lupo 2009; Villari 2012; Villari 2013).

[8] Cf. Manzini 2005; Manzini 2015.

[9] Cf. Krueger 1983.

[10] Cf. Milgram, Kishino 1994.

[11] Cf. Lanier 1992.

[12] Smart Specialisation Strategy is a place-based approach characterised by the identification of strategic areas for intervention based both on the analysis of the strengths and potential of the economy and on an Entrepreneurial Discovery Process (EDP) with wide stakeholder involvement. It is outward-looking and embraces a broad view of innovation including but certainly not limited to technology-driven approaches, supported by effective monitoring mechanisms.

[13] The images accompanying the text are taken from the work of two famous artists from the Marche region. Mario Giacomelli's photographs and Tullio Pericoli's drawings are evidence of the connection to their land of origin. They give us an abstract image made up of lines, scratches and textures that become signs and symbols of a language capable to speak about the landscape of Marche region.

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EFFECTIVE KNOWLEDGE EXPERIENCES. IMMERSIVE AND PARTICIPATORY SERIOUS GAMES FOR HERITAGE EDUCATION

Afterword

Effective knowledge experiences

In 2018, about 55 million people visited the museums of Mibac[1], an increase of about 10% compared to the previous year. As Mibac Museums General Director Antonio Lampis recalls, *"Few areas are growing by 5% these days. [...] I always remember that in museums the real result to aim for is not to sell tickets, but to be able to offer, as the rules say, real experiences of knowledge"*. This is the goal: to offer effective experiences of knowledge to visitors to museums, exhibitions and any other area in which you can be exposed to cultural heritage. Not entertainment, not only the cult of the past, but experiences that leave an indelible mark on visitors.
But how do you build an effective experience of knowledge?
In order to try to suggest a methodology it will be necessary to refer to theories of a general nature and then to decline them in the case of our interest.
In the psychological field, Jerome Bruner[2] reminded us that our thought is continuously poised between a logical-scientific dimension and a narrative dimension, where the latter refers to a deep, primordial need of our civilization to build meaning for the manifestations observable throughout life, or, in short, to interpret reality. If logical-scientific thinking provides clarity and organizes knowledge, narrative thinking investigates the polysemic value of knowledge and the experience of knowledge. In this indeterminate certainty, it allows individuals to find their own role within the narrative. About fifty years after the formulation of the first theories on narrative thinking, Bruner further deepened his studies underlining how two dimensions of narrative thinking are fundamental: the first is the "narrative creation of the self" as a fundamental component of the construction of a subjective dimension of identity, and the second is the interpretative dimension, which allows us to overcome the limits of given solutions[3]. Many other studies have developed individual aspects or entire theories of narrative thought, especially in the field of psycho-pedagogical sciences. Later literature[4] on the structuring of narratives useful for educational processes, have inspired some choices in the design of the Serious Game in the present work. Among other theorizations, the seven components to build a story, proposed by Norris et al.[5] - Event-tokens, Narrator, Narrative appetite, Past time, Structure, Agency, Purpose and Reader – seem to highlight important factors to be taken into account in the design of an educational path. In particular, the concept of narrative appetite[6], that is, the ability of a narrative to feed the desire to discover what will happen and how the story will end, is indeed really important when creating a very concrete experience of knowledge, as the one build in our proposal. In an essay on the cornerstone of digital techno-culture, Giuseppe Longo[7] offers us a gnoseological reflection, underlining the diametrically opposed nature between two profiles of knowledge construction that our civilization has developed over time: the first, of an archaic

profile, in which "knowledge [is] tacit, global and immediate, implemented by the body and embodied in its structure and its biological functions [...] guided by the affective and emotional system", and a second one, "more recent from an evolutionary point of view, [...] explicit knowledge, implemented in the forms of abstract logic and in general in rationality[8].
This new counterpoint between the emotional dimension and the rational dimension confirms how the dichotomy of the elaboration of our experiences at the psychological level necessarily requires a planning of museum experiences, or more generally educational, with an equally dichotomous approach[9].

Digital Heritage Education

The use of digital technologies for art and heritage education is a very current research topic[10] and the developments of digital representation technologies applied to heritage[11] have increased the possible interactions between previously distinct worlds. In particular, the use of serious games seems to be increasingly widespread in the context of Digital Heritage[12].
There are many reasons for this, but they can be summarised as follows: 1) cognitive involvement, 2) adaptation to the engagement strategies of generations Y, Z and Alpha (by designers of generation X), 3) gamification of increasingly widespread cultural and productive activities.
Digital technologies allow us to question heritage in a deeper way, and for this reason the digitization process should be a continuous commitment of all institutions and subjects that hold heritage: obsolescence and continuous updating make it difficult to maintain the standard, but it is a necessary price to pay for the protection of heritage itself. One of the main objectives of heritage education is to raise awareness of the need to safeguard and enhance heritage, which must become "endemic" if it is to be truly effective and sustainable. So everything that can be done in places where culture is "consumed" is useful for achieving this goal. Digital technologies, which have been part of our everyday lives for decades and are increasingly present in the development of interpersonal relationships, are the preferred platform on which to develop the processes of enhancement. Clearly without affecting, for example, the value of the real experience of heritage - unique and unrepeatable, according to current technologies - but increasing its scope in many ways. In *depth*, for example, by allowing those who visit a museum or heritage site to learn more about the collections or artefacts. In *amplitude*, interrelating what they have in front of them with similar objects in other places or with objects that have preceded or succeeded the one of our interest. In *modality*, varying the "human-heritage interaction" from medium to medium (panels, screens, touch tables, smart devices, VR viewers, etc.).

Serious Game

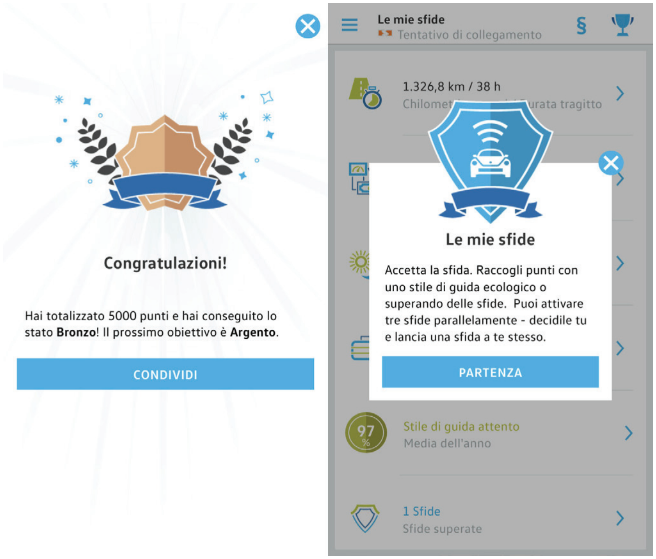

Fig. 1 - Two screens of the app connected to my car. The poitification should motivate me to have a more careful and ecological driving.

As already mentioned, the extension of gaming mechanisms to non-leisure activities is accelerating rapidly. In many work areas, a technique that can be defined as pointification - the payment of points to production activities carried out in production chains - is widespread. After the Washington Post article last May, it became globally known that in some Amazon sorting centers employees can freely choose to participate in video games such as “PicksInSpace”, “Mission Racer” or “CastleCrafter”. These simple applications shift the worker’s attention from the productive action (moving objects, filling packages) to reaching more and more “competitive” scores in the game. Motivation to achieve high performance in the game contributes to increased work performance.

Another example could be the use of many car manufacturers to include in their vehicle management apps some “points collected” with the possibility of starting “challenges”. (fig 1) with themselves. The application should motivate the driver to maintain a driving style that is environmentally friendly, traffic-safe and prudent. At the time of writing I have a “driving style I expect” to 97%. It is clear that this type of activity has little to do with cognitive involvement in a real game (fortunately pedestrians, as far as the applications of car manufacturers are concerned) because, in fact, the only aspect that is drawn from the game techniques is the motivation to achieve subsequent goals through the acquisition of increasingly high scores. The narration is completely missing (if we don’t want to elevate to “narration” the fact that driving more prudently or ecologically makes you a better driver...) and the dynamics of exploration, interaction and discovery of the unexpected are completely missing. To give a concrete example, it is sufficient to remember that one of the first actions that are carried out during the visit of a virtual environment - immersive or not -, is the search for the limits of navigation: how many times it has happened to you, after a few laps of track, to take the car off track to see where the "driveable" space ended, or after starting to interact in the game, explore far and wide the navigable space to understand the actual size. I don't think that any Amazon employee has ever tried to explore the "limits" of the space made available to him (in positive or in negative), under penalty of a call for trying to collect a "0" in a work shift to see what would happen... As I do, not think that he suddenly accelerated at each traffic light, always traveling in first or second gear even on the bypass, with the air conditioning on and the windows open to see how quickly the percentage of "green driving" in the application of my car drops.

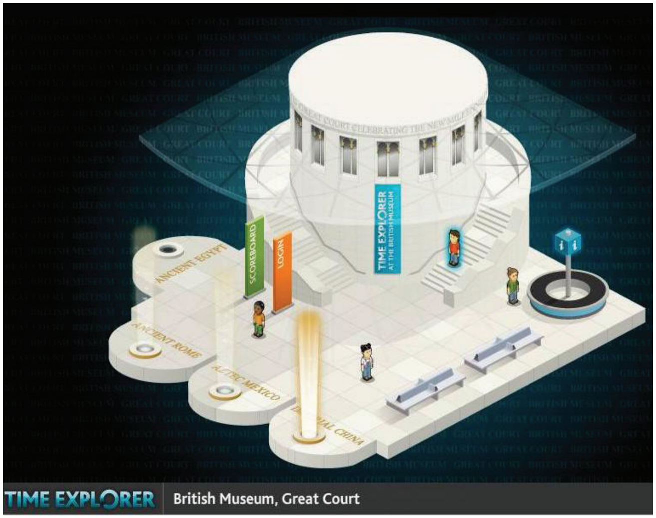

Fig. 2 - A Time Explorer screen, where you can see the Great Court with Norman Foster's intervention.

Heritage games

Bringing users closer to heritage through serious games means above all making a cultural experience enjoyable, making the path of knowledge individual, making our desire to approach heritage repeatable, whether it be tangible or intangible.

There are many experiences on this subject at an international level, and it will be useful to remember that for almost a decade, museum institutions such as the British Museum or the Tate modern have been directing their interests towards gamification with products, more or less successful and long-lasting, that have broadened the range of users interested in their collections and events.

Time explorer, (fig 2) published in 2010 by the British Museum and no longer available on the apple and google app shops, was an interactive video game with two-dimensional graphics, whose three-dimensionality is simulated by the axonometric projection of the scenes and the movement of the characters. The story started from the Great Court, the internal covered court in 2010, with a view that pays homage to the transparency of Norman Foster's work. From here unravel paths that lead the player (the age-target is 9-13) in ancient settings (the ancient Rome, ancient Egypt, etc.) in which to save objects

Fig. 3 - Screenshot of Great Fire 1666, where you see a reconstruction on Minecraft platform in London in 1666.

and collections from destruction or oblivion.

On January 4, 2012, the Tate Modern releases *Race against time*, the adventure of a "brave Chameleon" who must oppose a "diabolical" Dr. Greyscale (as they were described on the page of the Tate), identifying and collecting "colors" before Dr. Greyscale makes them disappear. The 12 scenarios are dedicated to the twelve decades that from 1890 to 2010 saw artistic movements follow one another in rapid succession. Tate's experience in building a dedicated space in Minecraft is also interesting: Mojang's sandbox platform is a space particularly suited to the development of playful applications with cultural content. It will be enough to remember, in addition to the experience of the Tate modern, the ambitious project *Great Fire 1666* of the Museum of London that in the 350th anniversary of the great fire has reconstructed the London of 1666[13] in three scenarios - before, during and after the fire - and the application of the Galleria Nazionale delle Marche with *Raphael in Minecraft*, or recent applications such as Florence in Minecraft of the Museo del Novecento of 2017 (fig 3).

The construction of digital spaces for heritage education, therefore, also passes through participatory processes and processes that do not provide for the satisfaction of the quality standards of heritage documentation for the protection: the enhancement, in this case, is more affected by the “accessibility” of the heritage, and for this reason new modes of engagement are symmetrically necessary for the advancement of surveying and modelling technologies.
Creating effective knowledge experiences, as we mentioned at the beginning, is necessary for every museum institution, for every exhibition curator and for every expert who lends himself to dissemination. Serious games are a tool, which in the case of cultural heritage has already shown a very appreciable adaptability. One of the policies to be developed is undoubtedly this, but with attention to the typical risks of gamification: entertainment must always be subordinate to content, and the increase in users does not necessarily represent a success of the application.

Alessandro Luigini

Notes

1 Data available on the website of the Ministry of Cultural Heritage and Cultural Activities, at the following link: http://www.beniculturali.it/mibac/multimedia/MiBAC/documents/1550245833146_2018_Musei_Tavola6_al_13-02-19.xls

2 Cf. Bruner 1956.

3 Cf. Bruner 2002.

4 Cf. Egan 1986; Toolan 2001; Norris et al. 2005; Avraamidou and Osborne 2009.

5 Cf. Norris et al. 2005

6 Cf. Norris et al. 2005, p. 541

7 Cf. Longo 1998

8 Cit. Longo, 1998, p.58

9 Cf. Luigini, 2019

10 Cf. Luigini and Panciroli 2018; Nuzzaci and Luciani 2018; Luigini 2019; Mandarano 2019; Macauda 2019.

11 Cf. Brusaporci 2017; Parrinello 2019

12 Cf. Anderson et al. 2010; Mortara et al. 2013; Champion 2016; Koutromanos 2016; Ioannides et al. 2017; Basso 2019; Paliokas 2019.

13 The experience of Great Fire 1666 is available at the link https://www.museumoflondon.org.uk/discover/great-fire-1666

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FROM HERITAGE TO MASSIVE FUTURE FRUITION

Postface

The European Commission, the research financed, the organizations that deal with the collection and enhancement of the historical heritage, whether they are artefacts in the open air or museum exhibits, indicate with increasing insistence the digitization as an essential process for the dissemination of our culture and its transmissibility. The digitization of whole cultural heritage sites is driven by the fear that natural or war events can erase them from our memory; moreover, when we deal with artefacts that are already part of collections or part of a museum, we are encouraged by the desire of a wider circulation in an era of cultural competition among institutions or sometimes with too difficult possibilities in circulation. Frequently we are faced with collections that are closed to the public or confined to areas that cannot be visited.
Preserving in a landscape like our, rich in artefacts but often lacking in dissemination out of its boundaries, is no longer sufficient; neither it is because we are in an area where historical research is relevant, progresses and widens its boundaries, placing itself in relation with other researches and traditions.
The creation of the first digital databases reveals an articulated panorama, full of attempts, or structure researches, where the hot topics deals with acquisition and reverse modelling themes, such as accuracy of the models and reliability; fast or automated methods of form extraction; semantic enrichment, or modelling for virtual or augmented fruition for dissemination.
Cultural heritage is transmitted us with a richness of meanings due to the interpretation of the space-time relations that forged it; however, its life now is restarted by the possibility that the technique offers together with the amount of data that belongs to it, the development of the way they are used. As in the next years much physical reality will be largely replaced by a digital reality the historical responsibility that the new digital models assume goes far beyond that of simple contemporary dissemination.
The generation of the - digital twins - of the heritage of the past is the bet on which the preservation of the historical heritage for the next generations is based as well as, in a similar field, the progress of new buildings is based.
The researches here produced emphasize three themes individually and as a whole: the method of acquisition and survey procedures as a research theme running; the aim of cataloguing and therefore the semantic enrichment of the objects produced; the possibility to forecast scenarios for future research and development.
The acquisition of the point cloud: assuming the fact that the digital model is a data repository coming from different sources that contribute to the description of the object, the first objective of the acquisition is to produce a metrically accurate 3D model, possibly provided with material representations faithful to the existing one.
The point clouds generated by laser scanners or the colorimetric information derived from photogrammetry require skills not easily available, and warn us about issues related to the accuracy of the models. While the lack of accuracy could be

negligible in some areas related to the use the survey for entertainment it can't be in the research field. As the accuracy of the point cloud falls proportionally to the number of different acquisitions made post processing phases need high skills to assure good results. More skills in texturizing phases or mesh modelling: reliability is an ambitious goal.
The aim of cataloguing: its structure and organization raises questions from the earliest stages of model segmentation and semantic enrichment of the objects that are identified within it.
The geometric segmentation in itself, sometimes automatically offered by software, may not make sense for some artefacts and implies again the intervention of the researcher that must know the structure of the final database. The enrichment of the model is determined by the materials found as well as by the need for dissemination: sometimes it is necessary to integrate historical information but also managerial or related to the type of maintenance as well as alphanumeric or multimedia data.
The purpose of the database must be defined from the beginning of the segmentation phase being plenty possibilities of its goal. The variables of the single researches offer often tailor-made workflows that demonstrate the state of the art and the difficulty of finding a completely shared procedure or even more model cataloguing standards.
If document digitization procedure of existing paper materials has produced regulations and by now consolidated rules the procedures for the digitization and cataloguing of monuments or artefacts of smaller size is far from such a scenario. In a foreign context, some large institutions such as the Smithsonian started in defining parametric parameters for the digitalisation of collections, currently offering traces or guidelines to support colleagues to build workflows by creating sustained high speed, high quality digitization processes, by pairing up the digital surrogates they create with the collection records stored in the various collection databases. It is about sharing a responsibility in finding, as Smithsonian says, the best technologies and processes to achieve these goals; to conduct mass digitization projects to test and implement these new technologies and processes; to educate and train ourselves to understand these new approaches; and finally to integrate digitization operations into the day-to-day operations in order to give the world access to the collection sometimes hidden the public.
Finally, the topics of future research progress for a wider fruition: as museums have not been immune to the advent of technologies linked to the world of Web-related technologies and generally to first-generation digitization and to the development of Web Pages (and social media in a second stage) the imminent moment seems to invoke research on the development of interaction between digitalization and technologies 4.0. The museums have realized the potentials of digital technologies on reaching a wide public and increase their attractiveness. Now that digital technologies offer some low-cost scenarios, as user-friendly tools, they multiply the way in which "users" use interactive technologies in their

everyday life, including visits to cultural places. We slide towards a digital enjoyment that does not therefore lend itself only to scientific research and dissemination but will allow the introduction of a wider public, friendly user, and all kinds of devices.
All these changes will oblige museums and institutions to think about reinventing themselves in more digital involving ways, where modelled contents accurate and reliable will be probably exported to a wider market; this last one will offer further experiences probably customized by the single user, founded on previous deep and accurate models previously acquired.

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DIGITAL GALLERY OF THE MAQUETTES

Elisabetta Caterina Giovanniini, Andrea Tomalini

European Heritage institutions galleries, libraries, archives and museums (GLAM) hold rich collections that represent Europe's cultural diversity and our shared history and values. Digitising and providing broader access to cultural resources offer new opportunities for the visualisation of collections and represent essential conditions for the further development of Europe's cultural heritage. The digital revolution highlights how Cultural Heritage institutions are turning online to engage with diverse audiences. Today the tools available can reach out a new and diverse public using the web through virtual exhibitions, online activities (e.g. games with cultural significance) and social media.

The B.A.C.K. TO T.H.E. F.U.T.U.RE. research project[1] follows this direction believing in the necessity to make cultural heritage accessible in a digital way, to promote culture using scientific content. As already described in *Part I* of this volume the project focused on a collection conserved in the Museo Egizio's depots: the 'Expedition models of Egyptian architecture' (EMEA). Since 1976[2] the role of depots is described as "*the museum's role as guardian, exhibitor and interpreter of cultural and natural objects and as a research institution*"[3]. A recent Italian ICOM initiative[4] entitled *The essential is invisible to the eyes. Between care and research, the potential of museum depots, was focused on the theme of museum depots*, their management issues and how digital technologies can contribute to their wider knowledge in term of research and communication to a wider public.

The theme of digital collections since the last decades covered mainly the needs to show collections improving the quality of visualisation tools to display objects. Some important initiatives were developed also to physically replace the museum itself, creating virtual museums. These solutions were developed to make both virtually accessible museums and to design new digital environments.

The Google Art Project[5] (February 2011), thanks to the Street View technology allows to virtually explore diverse museums all over the world, using 360° virtual tours. Nowadays this project is entitled The Google Arts & Culture[6] and since 2016 it started to digitise a large number of paintings and artefact using the Art Camera[7] creating new high-resolution digital assets. The Virtual Museum of Iraq[8] shows the collection and the objects are chronologically exhibited in different rooms using a diverse type of multimedia content.

The Guggenheim Virtual Museum (GVM) was initiated in 1999 and it was one of the first projects that had the ambition '*to develop a fully interactive and "immersive" architecture that would afford visitors the possibility to access, peruse, interact with and further explore contemporary mediated and technological art forms'* [9], but unfortunately, the project has not been fully completed.

Some European initiatives consider the term 'Virtual Museum' as a general one that covers various types of digital creations including virtual reality and 3D. The V-MusT.net[10] project (2011-2015) was one of the first European funded projects with the aim to resolve the problem of research in museums developing new solutions for sharing knowledge connecting different technological domains. The project provided also tools for immersive and interactive fruition of virtual environments. Crosscult[11] project (2016-2019) aim was to deliver tools to individuals and groups, for interactive experiences based on storytelling using the composition of digital cultural heritage resources, including 3D digital assets. 3D-ICONS[12] (2012-2015), was one of a suite of projects, to develop Europeana[13] and its contents. The project covered all aspects of 3D digitisation from selection of methods and tools, data acquisition and post-processing to publication of content online. GRAVITATE[14] (2015-2018) project objectives were to create a set of software tools that will allow archaeologists and curators to reconstruct shattered or broken cultural objects. At the same time, another important aim was to identify and re-unify parts of a cultural object that has been separated across collections and to recognise associations between cultural artefacts creating new knowledge.

The B.A.C.K. TO T.H.E. F.U.T.U.RE. research project follows these precedents adding a novel approach to document how different disciplines (geomatics, history, archaeology and architectural digital representation) interpret digitised sources. The digitisation process both for documentary heritage[15] and artefacts[16] were developed following established principles of the London Charter[17] for the use and re-use of computer-based visualisations by researchers, educators and cultural heritage organisations. Regarding the 3D models, considered as architectural digital representations, the International Principles of Virtual Archaeology (Seville Principles[18]) were used to develop 3D models used as visualisation tools able to clarify the relationship between architectural artefact and related digital assets. Some research projects that have dealt with the digitisation of museum collections have focused their attention on the visual appearance of the objects and not into its history and related sources.

The documentary heritage (eg. architectural drawings and manuscripts) and its digitisation developed within the project, used the ontology standard known as CIDOC-CRM[19] to take the advantages of semantic technologies and to manage the diverse knowledge domains involved, to select, organize and implement digitised sources.

Successful examples of the use of CIDOC-CRM into digital collections are the ResearchSpace[20] project, the Swiss Art Research Infrastructure[21] (SARI) project and the Digitizing Early Farming Cultures[22] (DEFC) project.

The previous examples enlight how the use of metadata in the digital collection research projects, is crucial to document and describe digital sources, historical documentation[23] and digitised objects, in our case, the 'Expedition models of Egyptian architecture' (EMEA). In this project, Cultural Heritage is the main domain, but other sub-domains have to be taken into account aiming to cover a real multidisciplinary approach enabling the interlinking of 3D content with different digital assets related to it. These connections were possible thanks to the use of descriptive and cross-disciplinary metadata.

Metadata means data about data and can provide extra useful information on data (digital resources). They play a key role in the project data management systems to allow wider searchability and deeper specific knowledge. The developed conceptual model allowed connecting 3D models with research sources highlighting their implicit knowledge and derived multidisciplinary explicit assumptions.

As already mentioned, despite the growth of diverse technologies, the core of main projects related to digitisation of cultural heritage stops to the visual appearance of the diverse objects or digitised documents. The B.A.C.K. TO T.H.E. F.U.T.U.RE novel approach is to create narratives and providing critical navigation into the digital collection and related contents[24].

Latest initiatives that go in this direction are the EMOTIVE[25] project (2016-2019), that produced interactive, personalised, emotionally resonant digital experiences for museums and cultural sites, and SHARE 3D[26] project (2018-2020) and its developed tool, the SHARE 3D Story Maker[27]. The innovativeness of the Story Maker is the possibility to share 3D content to Europeana, the EU digital platform for cultural heritage. The storytelling tool allows sharing stories of an object's history, characteristics, information trough metadata, selecting and reusing content from Europeana, Sketchfab and other sources, and linking them to create stories.
The following digital gallery of the *maquettes* is part of the digital content developed within the B.A.C.K. TO T.H.E. F.U.T.U.RE project. The digital models, provided using the 3D Hop[28] visualising tool are part of a series of digital contents that support the historical narratives developed by the interdisciplinary research team. From the historical documentation to its digitisation, from the museum collection to its digital collection, the research opportunities are quite vast, as vast are the new stories and intersections created and discovered trough the project evolution path.

Notes

[1] Cf. Lo Turco et al. 2018.

[2] International Conference on Museum Storage was proposed by UNESCO and was held on December 13-17, 1976, in Washington DC.

[3] For an exhaustive list of key documents supporting the discussion see Froner 2018, pp. 9-10.

[4] http://www.icom-italia.org/eventi/save-the-date-15-16-marzo-2019-matera-convegno-sui-internazionale-sui-depositi-museali-e-assemblea-annuale-dei-soci/ Last visit, March 2020.

[5] Cf. Kennicott 2011.

[6] https://artsandculture.google.com/ Last visit, March 2020.

[7] The Art Camera developed by Google use a "gigapixel" process that stiches together multiple high-resolution images with an average of 7 billion pixels. Cf. Kennicott 2011.

[8] http://www.virtualmuseumiraq.cnr.it/ Last visit, March 2020.

[9] Cit. Rashid 2017.

[10] http://www.v-must.net/home Last visit, March 2020.

[11] https://www.crosscult.eu/ Last visit, March 2020.

[12] http://3dicons-project.eu/ Last visit, March 2020.

[13] Europeana is a web portal created by the European Union containing digitalized collections owned by European galleries, libraries, archives and museums (GLAM); https://www.europeana.eu/en Last visit, March 2020.

[14] https://cordis.europa.eu/project/id/665155 Last visit, March 2020.

[15] See *Digitalizing Data: from the historical research to data modelling for a (digital) collection documentation*, pp. 39-51.

[16] See *Digital models of architectural models : from the acquisition to the dissemination*, pp. 53-65.

[17] http://www.londoncharter.org/ Last visit, March 2020.

[18] http://smartheritage.com/seville-principles/seville-principles Last visit, March 2020.

[19] CIDOC, the International Council for Documentation, is a committee of the International Council of Museums (ICOM). CIDOC Conceptual Reference Model (CRM) is a standard ISO 21127:2014 in the field of cultural heritage. The CIDOC CRM ontology is complemented by a series of modular extensions to the basic model. Such extensions are

designed to support different types of specialised research questions and documentation.

[20] The ResearchSpace project emerged from an idea for a shared digital research infrastructure proposed by the Andrew W. Mellon Foundation. ResearchSpace is an open source platform designed at the British Museum and retrievable at https://www.researchspace.org/index.html Last visit, March 2020.

[21] The Swiss Art Research Infrastructure (SARI) is a national research infrastructure providing unified and mutual access to research data, digitised visual resources, and related reference data in the field of art history, design history, history of photography, film studies, architecture and urban planning, archaeology, history studies, religious studies, and other disciplines related to the visual studies, as well as the digital humanities at large. https://www.sari.uzh.ch/en.html Last visit, March 2020. The SARI documentation used for the semantic web infrastructure and its Reference Data Model is retrievable at https://docs.swissartresearch.net/ Last visit, March 2020.

[22] https://defc.acdh.oeaw.ac.at/ Last visit, March 2020.

[23] The historical documentation gathered, consists of digitized document and drawings of the sculptor Jean Jacques Rifaud (Marseille 1786 - Genève 1852) conserved at the *Bibliothèque de Genève*.

[24] *Cf. Lo Turco et al. 2019*

[25] https://emotiveproject.eu/ Last visit, March 2020.

[26] https://share3d.eu/ Last visit, March 2020.

[27] https://storymaker.share3d.eu/home Last visit, March 2020.

[28] http://vcg.isti.cnr.it/3dhop/ Last visit, March 2020

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Temple of Dakka

Temple: Cat.7109
Propylaea: Cat.7101
Scene elements: 3
Url: https://backto-thefuture.github.io/temple-of-dakka.html

Temple of Debod

Temple: Cat.7105
Portals: Cat.7111
Scene elements: 3
Url: https://backto-thefuture.github.io/temple-of-debod.html

Temple of Dendur

Temple: Cat.7108
Portal: Cat.7108
Scene elements: 3
Url: https://backto-thefuture.github.io/temple-of-dendur.html

Model of the Temple of Dakka (Propylaea)

Propylaea: Cat.7101
Scene elements: 1
Url: https://backto-thefuture.github.io/propylaea.html

Model of the Temple of Abu Oda

Temple: Cat.7102
Scene elements: 2
Url: https://backto-thefuture.github.io/abu-oda.html

Model of the Temple of Beit el-Wali

Temple: Cat.7103
Scene elements: 2
Url: https://backto-thefuture.github.io/beit-el-wali.html

Model of the Small Temple of Abu Simbel

Temple: Cat.7104
Scene elements: 2
Url: https://backto-thefuture.github.io/abu-simbel.html

Model of the Temple of Debod

Temple: Cat.7105
Scene elements: 2
Url: https://backto-thefuture.github.io/debod.html

Model of the Temple of Gherf Hussein

Temple: Cat.7106
Scene elements: 2
Url: https://backto-thefuture.github.io/gherf-hussein.html

Model of the Temple of Tafa South

Temple: Cat.7107
Scene elements: 2
Url: https://backto-thefuture.github.io/tafa-south.html

Model of the Temple of Dendur

Temple: Cat.7108
Scene elements: 2
Url: https://backto-thefuture.github.io/dendur.html

Model of the Temple of Dendur (Portal)

Portal: Cat.7108
Scene elements: 2
Url: https://backto-thefuture.github.io/portal.html

Model of the Temple of Dakka

Temple: Cat.7109
Scene elements: 2
Url: https://backto-thefuture.github.io/dakka.html

Model of the Temple of Tafa North

Temple: Cat.7110
Scene elements: 2
Url: https://backto-thefuture.github.io/tafa-north.html

Model of the Temple of Debod (Portals)

Portals: Cat.7111
Scene elements: 1
Url: https://backto-thefuture.github.io/portals.html

Model of the Temple of Derr

Temple: Cat.7112
Scene elements: 2
Url: https://backto-thefuture.github.io/derr.html

Model of the Temple of El-Hilla

Temple: Cat.7113
Scene elements: 2
Url: https://backto-thefuture.github.io/el-hilla.html

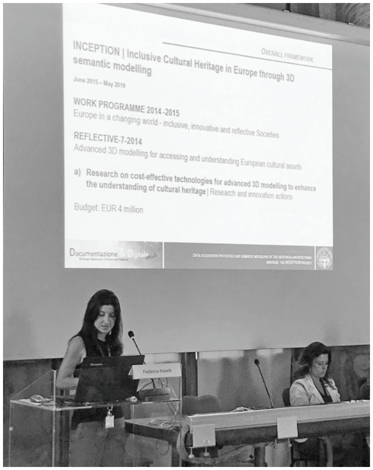
Model of the Obelisk of Heliopolis

Obelisk: Cat.7115
Scene elements: 1
Url: https://backto-thefuture.github.io/obelisk.html

EVENT PHOTO GALLERY

Elisabetta Caterina Giovanniini


Documentazione & Digitale
Michele Calvano
Politecnico di Torino
Disegno Digitale Esplicito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June 2015 – May 2019
WORK PROGRAMME 2014-2015
Europe in a changing world - inclusive, innovative and reflective Societies
REFLECTIVE-7-2014
Advanced 3D modelling for accessing and understanding European cultural assets
a) Research on cost-effective technologies for advanced 3D modelling to enhance the understanding of cultural heritage | Research and innovation actions
Budget: EUR 4 million


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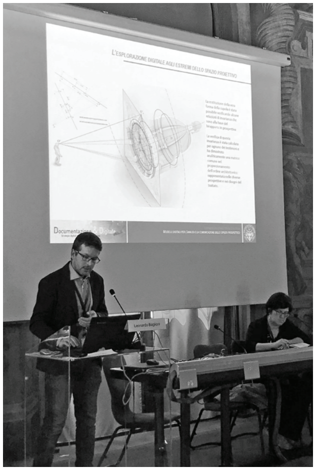
1824
Modellini "didattici"?


VIRTUALITICS
Documentazione

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Ambienti digitali Per l'educazione all'arte e al patrimonio
ALESSANDRO LUIGINI


DIGITAL & DOCUMENTATION


Scenario di progetto


MUSEI DI
COLLEZIONE
MUSEI DI
NARRAZIONE

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Cultural Heritage is as rich as complex and its documentation is an increasing challenge. The digital solutions are numerous and their potential is a topic of constant investigation by the scientific community, that is requested to deliver digital strategies to make heritage permanently open and shared. The volume collects the contributions to the second conference of the 'Digital & Documentation' series, extending the debate to a multidisciplinary network of experts. It presents a frame of strategies for the documentation of Cultural Heritage in a wider perspective, stimulating reflections on: the relationships between physical and digital assets; the consistence of digital data and its management; digital representation as a mean to the transfer of cultural heritage. It comprehends theoretical studies and best practices on tangible and intangible heritage, taking into account applications for the research and the communications of Cultural Heritage as 3D representations, digital anastylosis, Augmented and Virtual Reality, Artificial Intelligence, semantics and databases. Aiming to give a comprehensive view on digital and documentation, the volume involves multiple perspectives from cultural institutions and universities, from experts in representation, geomatics, history, architecture, archaeology and ICTs for a multidisciplinary outcome.

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