REPRESENTATION CHALLENGES
Augmented Reality and Artificial Intelligence in

disègno

the Series of the UID – Unione Italiana per il Disegno

director Francesca Fatta

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REPRESENTATION CHALLENGES
Augmented Reality and Artificial Intelligence in Cultural Heritage and Innovative Design Domain

edited by

Andrea Giordano
Michele Russo
Roberta Spallone

FrancoAngeli OPEN ACCESS

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Preface

Francesca Fatta

When in January 2020 Roberta Spallone with Andrea Giordano and Michele Russo proposed a seminar with the complex acronym REAACH–ID to involve a larger group of Augmented Reality scholars, I realized that the time had come to define the context of our initiatives on virtual representation, looking also to the sphere of science that deals with Artificial Intelligence. Their proposal did not want to follow the trend, but rather to respond to the need for methodological relationships and cross competences aimed at promoting a dialogue between human and hard sciences.

The starting point consists in the single and shared researches of the scholars involved in the organization of this symposium, they are all teachers of Drawing who have been engaged for years in the creation and analysis of drawings, images and models that represent the evolution of existing realities over time or purely designed entities. Moreover, when the Italian teachers of Drawing reorganized the declaration of the sector (UID May 2021), they agreed that the scope of our SSD (Scientific Disciplinary Sector) research: "[…] therefore concerns the geometric–descriptive–configurative domains, graphic–visual–synaesthetic, informational–computational features, as well as the related historical, epistemological, semantic, technological and applicative aspects. [...] the modeling, including informative modeling, prototyping and visual communication [...]".

The question concerns the definition of the relationships between a physical, real, tangible reality and an intangible spatiality defined with the help of Artificial Intelligence, increasingly able to trigger specific reading processes of complex contexts, which can be represented in a way similar to human thought with amazing space–time simulation effects.

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Mario Rasetti's prestigious speech performed for the opening of REAACH–ID symposium indicated how Artificial Intelligence may show new possibilities in the world of representations, underlining the links between AI and Engineering, Information Technology, Cognitive Sciences and Philosophy.
During the symposium the scholars asserted several times that reality means everything that is concrete and material, therefore something natural and changeable, but the advent of Artificial and Virtual Reality offers a new version of reality in itself. It cannot be considered anymore as pure vision, but as a participation of all the senses, even of the whole body, thanks to effects created by the digital tools which are so likely that they are accepted by an observer as a real experience.
It has been noted that artificial reality is the most advanced form of interaction between man and machine. Inside this deceptive reality everything that is perceived is generated by a computer that responds to our movements with images and sounds designed to give us the illusion of a virtual world that breaks the laws of physics projecting our self in a free space–time. Artificial Reality represents the realization of an invention, a trespassing tool towards a new kind of utopia.
If it is true that Artificial Reality involves all the senses with illusory messages, nevertheless visual messages have the upper hand over all the others; it is precisely for this reason that during the symposium the scholars have exalted the world of Artificial Reality as a real opportunity for exploring and visual communicating. The user, wandering without constraints into a new world, becomes an experimenter of new models of thought and technologies.
Furthermore, researchers in our disciplinary sector often study cultural heritage resorting to digital technologies that increase their reading and interpretation in the process of its analysis, design and enhancement. For over fifteen years, the Italian teachers of Drawing have already made use of a fruitful intertwining between Artificial Intelligence and Augmented Reality thanks to the new possibilities of identification and connection between digital products and physical consistencies, in a mix of real and virtual world.
The way of acting, according to the methodological profile of our research, which starts from physical space, has found in the digital world and Artificial Intelligence those tools for expanding the reality (for this reason called "augmented") aiming at redefining the way to share cultural heritage, or the way to enhance it through innovative systems of community participation.
The success of REAACH–ID encouraged Roberta Spallone, Andrea Giordano and Michele Russo to organize a second symposium. For this I feel the need to thank them for the good work produced in this volume, which collects the results of the open discussion and the scholars' research presented during the first symposium, as well as for what they are preparing in the next future meeting.

UID president
July 2021

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Representation Challenges: The Reasons of the Research

Andrea Giordano
Michele Russo
Roberta Spallone

Augmented Reality (AR) and Artificial Intelligence (AI) are technological domains that closely interact with space at architectural and urban scale in the broader ambits of cultural heritage and innovative design. The growing interest is perceivable in many fields of knowledge, supported by the rapid development and advancement of theory and application, software and devices, fueling a pervasive phenomenon within our daily lives. These technologies demonstrate to be best exploited when their application and other information and communication technology (ICT) advancements achieve a continuum. In particular, AR defines an alternative path to observe, analyze and communicate space and artifacts. Besides, AI opens future scenarios in data processing, redefining the relationship between man and computer.

In the last few years, the AR/AI expansion and relationship have raised deep trans–disciplinary speculation. The research experiences have shown many cross–relations in Architecture and Design domains. Representation studies could arise an international debate as a convergence place of multidisciplinary theoretical and applicative contributions related to architecture, city, environment, tangible and intangible Cultural Heritage.

A research synergy between different Universities (Politecnico di Torino, University of Padua, Sapienza University of Rome) was the first occasion to share collected experiences. The discussion between scholars led to the importance of fixing a first state of the art about AR/AI topics in the national Representation area, analyzing the role of AR/AI in the chain of knowledge. Besides, critical interest has been focused on exploring the disciplinary boundaries, identifying affine disciplines involved in similar research, and activating

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effective relationships. Working beyond the usual research edges meant evaluating whether our discipline could expand its field of action, establishing as challenge new directions of research, possible partners, priorities, and objectives.
Our initiative started in the fall of 2019, with a series of international events related to research works based on possible intersections between AR and AI and the world of Representation. The importance of opening a discussion with our colleagues at national level was confirmed during these events, which were supported by Francesca Fatta [1], who advocated a meeting initiative. So, we created a first working group, formalized in the Scientific Committee, which includes the promoters: Francesca Fatta, Salvatore Barba, Marco Giorgio Bevilacqua, Stefano Brusaporci, Alessandro Luigini, Cettina Santagati and Alberto Sdegno. This group discusses the possibility to organize a Symposium intended as a national meeting framed in the Representation field, which took place online on 13 and 14 October 2020, managed by the Zoom platform of the University of Padua (fig. 1). The call for this virtual event met the interest of 175 authors, mostly coming from national Universities, proposing 83 research experiences. The proposed topics were divided into three main areas of interest: Augmented Reality, Artificial Intelligence, Virtual Reality & Digital Modeling. The related abstracts were reviewed and divided into 44 oral and 39 video presentations. This division wanted to preserve the duration of the event (two days) giving to everyone the opportunity to present their research. The video presentations were uploaded before the beginning of the conference on a dedicated YouTube channel and shared with all Symposium participants. In addition, the final recordings of the event were uploaded on the same channel, ensuring that all contributions could be reviewed. The Symposium counted 265 scholars during the two days (fig. 2). The meeting days were structured with plenary communications, proposing eight thematic sessions. After a brief introduction by the UID President (Francesca Fatta) and by the three organizers, each day featured four sessions, opened by a keynote speaker. The seven invited speakers belonging to different disciplinary fields showed the potential of AR and AI in their specific discipline, highlighting, on the one hand, the possible connections with the field of Representation while confirming the value of the transdisciplinary nature of our studies. The invited speakers were Mario Rasetti (ISI Foundation), Claudio Casetti (Politecnico di Torino), Michele Bonino (Politecnico di Torino), Simone Milani (University of Padua), Fabrizio Lamberti (Politecnico di Torino), Eleonora Grilli (Fondazione Bruno Kessler – FBK), Alberto Tono (Computational Design Studio – Studio HOK).

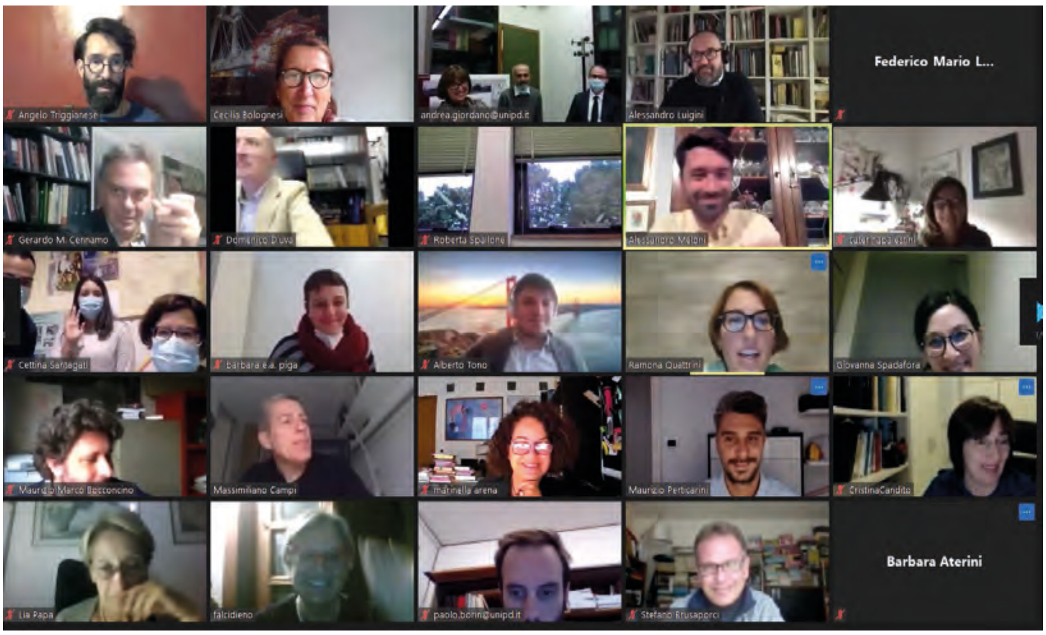

Fig. 1. Snapshot of the Zoom platform during the conference. Editing: M. Russo.

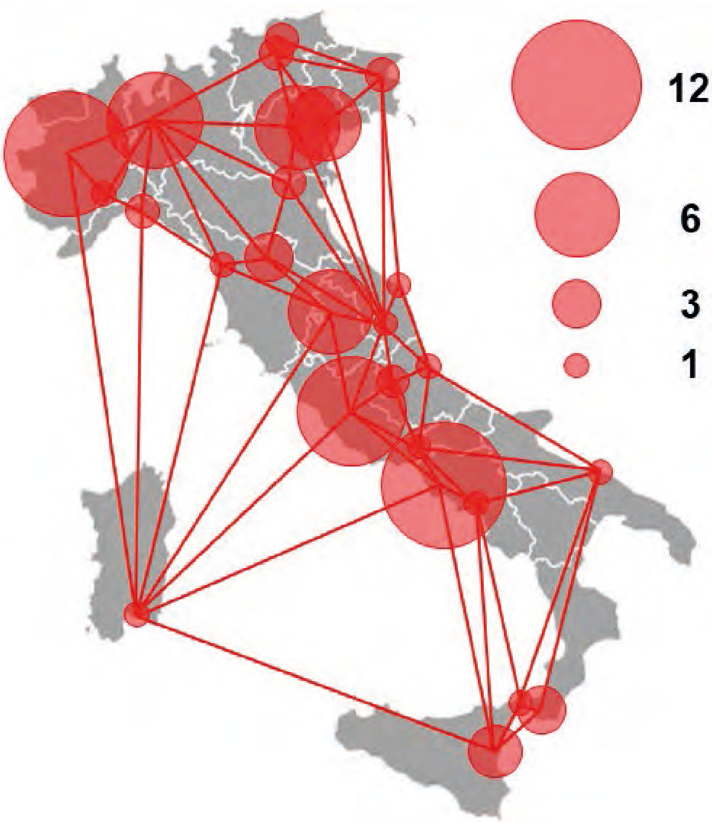

Fig. 2. Spatial diagram showing the distribution of research scholars accepted at the Symposium. Editing: M. Russo.

The volume that we are printing today follows the steps of the Symposium: the discussion that emerged from it has fed the proposal of the published essays, which have been subjected to peer review. In addition, the request to prepare a research paper after the meeting gave the authors the possibility to frame their research experience in an aware context, suggesting cross–references with other colleagues. The themes developed were collected in eight lines described below, which may guide future research developments.

AR&AI Theoretical Concepts

While augmented reality has been part of the disciplinary interests of Representation for at least twenty years, the much more recent developments in artificial intelligence and the possibilities of connecting the potential of the two technologies triggered significant theoretical reflections. The contributions in this section of the book range from the historical and cultural background, to the possible challenges of Representation, opening to other areas of knowledge.
An historical excursus has been traced by **Alberto Sdegno** who brings to attention the concept of 'Drawing Automata' that he discusses in the sense of automata that draw. The author crosses some singular experiences like those with 'mechanical puppets', up to developments in graphic technology for digital drawing, since the first virtual reality systems and the use of artificial intelligence aimed at shape recognition. Finally, he affirms that, in his opinion, the most interesting experiments will be the ones carried out in the field of shape grammars, and in particular those in which the role of architecture is involved.
The link with disciplinary roots is explored by **Francesco Bergamo** who tries to answer one of the core issues of the discussion: the role of Drawing in representing and designing new epistemological models during the current AI spread, especially in relation to today's available advanced tools. He observes that Drawing always played a major role in modeling knowledge and explains that the technical achievements, deployed while facing the current challenges, should be connected with the historical and critical background pro-

vided by the genealogies of perspective and maps. On the same line, **Marco Vitali, Giulia Bertola, Fabrizio Natta & Francesca Ronco** note that the links between Representation and artificial intelligence involve many fields of architectural research, recording continuous and significant advances that require a constant update of the state of the art and a careful consideration of the role of Representation in interdisciplinary researches. For this reason, they investigate the most cutting–edge case studies in the fields of Cultural Heritage, Museums, and Digital fabrication.
Then, **Giorgio Buratti, Sara Conte & Michela Rossi** explore the new frontiers of AI applied to Cultural Heritage and identify three main lines of research in this field that exploit the synergy between machine learning, big data and AI. They deal with: the development of innovative methodologies and systems to monitor and prevent damage to the cultural heritage; the experiments that focus on automatic data acquisition, such as the application of mobile technologies for three–dimensional surveying and acquisition of CH images; the management of large amounts of analog or digital data and information. Also **Valerio Palma** notices the unprecedented opportunities of advances in information and communication technologies for the documentation and analysis of architectural and urban assets. Nevertheless, he warns of the risk that the schematic understanding of reality produced by eidomatic tools, i.e. automatic recognition and classification become a black box, that is, algorithms we accept the results without questioning how these are produced or whether they can be adapted to changing needs. Then, Palma summarizes three connected research experiences he has been part of. They produced apps and prototypes exploiting geospatial databases, AI for image recognition, and AR based on model tracking, applied to architectural heritage, contributing an insight on the interpretation of the built environment form as a means to produce shared knowledge and operational outcomes.
Other authors develop broader reasoning regarding the design and ethical impact of new technologies. It is the case of **Claudio Marchese & Antonino Nastasi** that observe, in the digital age, the persistence of time and space as coordinates for human presence and their intrinsic relationship with Architecture. They analyze as sort of 'scenarios' concerning prefiguration, measurements, and relationships, dealing with AI and AR combinations in a projectual perspective. Moreover, **Marco Ferrari & Lodovica Valetti** analyze the ethical issues triggered by the integration of new technologies in the management of Cultural Heritage, in particular historical sites and museums, related to ontological, economic, and social aspects, trying to outline some principles able to limit these critical implications. They focus on the authenticity of reproduction, the costs of VR and AR systems, and individualism due to the use of personal devices. The scholars conclude that the relationship between man and machine and the concepts of real and virtual must be kept at the center of innovation and application in this field.

AR&AI Virtual Reconstruction

Digital convergence in the last decades has favored the development of virtual reconstructions for heritage enhancement. These are connected with documentary analysis and digital survey, dialoguing both with textual, iconographic and archival sources, and with artistic, archaeological, architectural and urban consistencies. Artificial intelligence and augmented reality are intertwined with knowledge, interpretation and communication, enhancing the value of virtual reconstructions from the point of view of scientific validation, knowledge construction, and inclusion.
The dialogue with architectural literature is interwoven by **Alessio Bortot**, who develops his reasoning connecting the treatise of stereotomy by Monduit with AR technology with the aim to better describe the tracing of stone cutting. Starting from the interest for de La Rue stereoscopic approach, which gives the opportunity to go beyond the two–dimensional limits of paper surfaces, such as the use of pop–ups, the scholar proposes the use of AR for creating digital pop–ups. The reconstructive 3D models of the treatise plates were provided with different semantic values and, through AR, could be visualized and split into blocks, while the relationship between form and structure was shown through the use

of a false color Fem analysis. Similarly, **Cristina Càndito, Andrea Quartara & Alessandro Meloni** study the scientific sources to deal with the representation of six Keplerian stellated dodecahedrons in the decoration of an aulic room in an historical palace in Genoa. Through the virtual reconstruction of the illusory space frescoed on the vault, they illustrate in a communicative, but not simplified way, through an immersive AR experience, the connections between the Genoese decoration and the wider seventeenth–century scientific milieu.

The analysis of archival and bibliographical sources, coupled with digital survey, supports the considerations of **Maria Grazia Cianci, Daniele Calisi, Sara Colaceci & Francesca Paola Mondelli** in light of the assignment by the municipality of Rome for the realization of three competition dossiers. They reflect on how and to what extent the Public Administration can now benefit from new technologies and digital tools, and conclude that although the current huge step is towards the digitization of the architectural heritage, it is also desirable to proceed towards Virtual Reality to ensure immersive design for competitors. Also **Maurizio Marco Bocconcino & Mariapaola Vozzola** present remarks that focus on analysis at urban scale, in order to propose, in this case, solutions aimed at safeguarding memory. They show the methodological framework for a research project on conservation and care of the memory of changing urban contexts and highlight the need of implementation of integrated digital archives with interactive and hypertextual navigation between the assets themselves.

Virtual reconstructions, linked to AR and AI technologies, are particularly developed in the archaeological field. It is the case of the research by **Riccardo Florio, Raffaele Catuogno, Teresa Della Corte & Veronica Marino**. They set up a methodology to deepen the investigation on the current consistencies of the Roman bath of Cumae that, through the preparation of a suitable neural network managed by AI processes, are able to formulate reconstructive hypotheses with scientific authority. Moreover, through the adoption of web–based and open source technologies and the applications of AR and interactive digital visualization, multiple information are associated with the 3D model. Also Maurizio Perticarini & Chiara Callegaro deal with archaeological heritage and propose the creation of an adaptive AR app with the aim to enhance through cultural tourism the vestiges of ancient buildings hidden by urban building development of Padua. The workflow identifies a path through the city and connects the analyzed and represented artifacts through documents, digital survey, BIM modeling and, finally, AR app, foreseeing further insights through artificial intelligence to differentiate the contents according to the user's preferences.

Finally, **Antonio Calandriello** exploits ICTs, i.e. digital reconstruction, virtual and augmented reality, video production, and application development, aimed at the enhancement of a Renaissance palace in Padua. In this way, it is possible to increase the inclusiveness and raise the level of use, giving visitors the opportunity to virtually visit the building and its precious frescoed halls, which the public cannot visit.

AR&AI Heritage Routes

Built and environmental heritage are very often made up of a series of artefacts and elements that take on a particular value in their constitution as a system. The construction and use of heritage routes can profitably avail of augmented reality and artificial intelligence technologies for the construction of knowledge and its sharing as well as for flow control and route recommendation. The researches presented in this section demonstrate the desire to create closer links between the real and the virtual sets, realizing a real continuum between them.

In this sense moves the work of **Stefano Brusaporci, Pamela Maiezza, Alessandra Tata, Fabio Graziosi & Fabio Franchi** dealing with the idea that a smart heritage could be realized through VR/AR/MR combined with AI applications. Their observations are based on a wide experience on the territory of L'Aquila that highlights the potential of the so–called 'phygital' with the protection and enhancement of assets often characterized by important elements

of fragility. In the same direction, although referring to environmental heritage, **Alessandra Pagliano, Greta Attademo & Anna Lisa Pecora** propose a systematization of the knowledge of the Phlegraean Fields Park, through surveys and 3D models, integrated by the use of different digital technologies, AR in particular. Each site becomes the node of a network of thematic routes, traced starting from the major attractions of the area. The goal is to define a hybrid landscape, made of site specific visits and digital experiences, that generate a new model of inclusive museum, configuring cultural relationships between physically distant places. Also **Andrea Rolando, Domenico D'Uva & Alessandro Scandiffio** work on environmental heritage enhancement. They aim at investigating the potential of image segmentation technology, based on web application, for measuring the spatial quality of slow routes. The method has been applied to some stretches of slow–mobility routes that are localized along a fragile coastal landscape of southern Italy. Such an update of the tool could take advantage of Machine Learning systems, namely the ability to learn through analysis, to improve its precision and reliability.
The research of **Gerardo Maria Cennamo** is engaged in the so called 'open air museums' linking in a single path a series of cultural stops. The author refers to two ongoing experiences in Naples and Rome where, thanks to GPS systems it is possible to develop dynamic paths of perception of the archaeological and architectural heritage, integrated by augmented reality applications that realize an active involvement of the visitor through pedestrian and vehicular itineraries.
Educational aims address the cutting–edge research by **Alessandro Luigini, Stefano Brusaporci, Alessandro Basso & Pamela Maiezza** that present a project addressed to the documentation, investigation of architectural values, and valorization of a Sanctuary in Pescara, through an application of augmented reality technology, able to visualize the previous configuration of the church, enhanced by an artificial intelligence–based tracking application. The awareness–raising program includes online communication and activities with local schools. Also **Serena Fumero & Benedetta Frezzotti** describe a didactic experience related to the use of AR in the promotion of heritage sites. The low cost and the relative ease of creating content of the cultural experience will encourage a similar approach in many other heritage sites.
The heritage route set up by **Marinella Arena & Gianluca Lax** develops a strategy to guide users and scholars in the Byzantine iconographic world, highlighting the elements that contribute to recognizing the sacred figures represented. The artificial–intelligence–based technique used to analyze 19 images of Saint Nicholas set up some preliminary strategies for the morphological classification of the iconography through the identification of the proportional relationships between the parts of the face.
In an original way, **Ornella Zerlenga, Vincenzo Cirillo, Massimiliano Masullo, Aniello Pascale & Luigi Maffei** create a philological heritage route investigating the ephemeral architecture of the eighteenth century in Naples. The goal is an unprecedented representation, modeling and fruition project, accompanied by a graphic visualization of the places to better understand the architectural and urban space. An Augmented–Reality application prototype makes it possible to disseminate the compositional elements of the celebrations to a non–specialist public.
Finally, **Giorgio Verdiani, Ylenia Ricci, Andrea Pasquali & Stéphane Giraudeau** set up a real route between different research experiences personally carried out, that links together digital modelling of no longer and still existing architectures with AR, VR and XR experiences. Not only in the will of capturing the users, but in the true belief that Digital Heritage is an occasion allowing an easier reading and an option for spreading the knowledge of Cultural Heritage.

AR&AI Classification and 3D Analysis

AR & AI classification and 3D analysis is an increasingly important area of research through data segmentation and attribution of specific connotations, supporting the architectural analysis process. In particular, the research focus shifts from 3D acquisition to data processing, defining hierarchical–oriented information systems. This strategy implements the geometrical data structures for reality–based and interpretative definition of model, optimizing the model communication passage through AR/MR/VR systems. The papers cover the entire process, from the treatment of the survey data to the Scan–to–BIM passage, up to the building's analysis and digital heritage enhancement.

The first group of articles is oriented towards photogrammetric techniques underlying data processing. **Marco Limongiello & Lucas Matias Gujski** work directly on data acquired by UAV imagery. They suggest an innovative approach that can support survey methods by applying AI algorithms, improving the accuracy of extracted point clouds. Some parameters are analyzed through a Self–Organizing Map (SOM) to reach a compromise between the variable values, the noise reduction, and the 3D model definition, allowing a fast data clustering. Similarly, **Andrea Tomalini, Edoardo Pristeri & Letizia Bergamasco** start from the UAV imaging approach and suggest the use of a photogrammetric model to generate new image datasets for training Machine Learning (ML) algorithms and recognize built heritage. They apply Physically Based Rendering (PBR) tools to extend the image datasets with artificial data. In the end, **Pierpaolo D'Agostino & Federico Minelli** propose a methodology for the automated delineation of brick masonries from images to a vector representation. The edge detection and vector delineation of brick joints allow a brick clustering for masonry classification, implemented in AR visualization.

The second group is oriented to the segmentation of point clouds acquired by 3D scanners for data classification with the aim to study architecture. **Michele Russo, Eleonora Grilli, Fabio Remondino, Simone Teruggi & Francesco Fassi** present an iterative multi–level and multi–resolution classification process that improves the learning activity based on a supervised automatic Machine Learning approach to optimize 3D point cloud classification by a hierarchical concept. This strategy requires few annotated 3D data while very detailed semantic segmentation results can be achieved. P**aolo Clini, Roberto Pierdicca, Ramona Quattrini, Emanuele Frontoni & Romina Nespeca** suggest an innovative approach based on HBIM existing models to improve the segmentation of 3D point clouds through the Deep Learning approach. The proposed methodology facilitates Scan–to–HBIM passage, generating a sufficiently large data set of synthetic clouds to train the neural network. The last paper referred to this cluster is a work by **Federica Maietti, Marco Medici & Ernesto Iadanza** and focuses on AI and 3D point cloud models, showing a new integration within the BIM environment, image classification algorithms, point cloud segmentation, and representation models. This paper presents a preliminary experience focused on the AI for processing the large amount of data obtained from digitization processes applied to the Architectural Heritage.

In the last three research papers, the modeling activity based on acquired geometrical data assumes a strategic value. In such a sense, **Elisabetta Caterina Giovannini** presents an extended analysis of the current methodologies and workflows for data modeling in Architecture, deepening the use of standards, descriptive metadata, and ontologies for Cultural Heritage representation. Furthermore, this research underlines the complexity of creating conceptual models able to manage three–dimensional data and descriptive metadata on architectural heritage documentation.

The last two articles share common themes of museums and IT, though explored from two different points of view. **Massimiliano Campi, Valeria Cera, Francesco Cutugno, Antonella di Luggo, Domenico Iovane & Antonio Origlia** propose a methodology of collecting, analyzing, and modeling multimodal data, helpful in designing virtual agents in 3D museum environments. This research is part of the national CHROME project, which deepens the interconnections between representation, survey, and information technology domains. The architecture focuses on graph databases and 3D models, using modern peripheral devices and third–party services for capturing and analyzing input signals; it also integrates probabilistic decision–making systems for controlling interaction in 3D environments. Besides, **Marco Giorgio Bevilacqua, Anthony Fedeli, Federico Capriuoli, Antonella Gioli, Cosimo Monteleone & Andrea Piemonte** focus the attention mainly on the communication museum strategy. They suggest a new visit path based on immersive experiences of video mapping, VR/AR, sound immersion, informative totems, audio–visual supports, and multisensory activities. The project aims to investigate the potential in applying new AR/VR technologies to enhance virtual tours and interpret 3D models of real environments.

AR&AI Urban Enhancement

This section is dedicated to research that refers mainly to the urban space and the territorial scale, considering also building knowledge connected to the territory and the architecture culture. The central topic of this section is the cultural and sensory itinerary, allowing experiences that go beyond the visible. The use of immersive and augmented virtual reality techniques creates a link between the tangible and intangible, memory and existing real space, underlying the construction logic, the building itineraries spreading knowledge. Both urban systems and single buildings are spatial and historical landmarks. Their disappearance or damage may erase the relation between present and past, causing a sense of disorientation. The first articles explore AR/VR methodologies for the memory recovery of places destroyed by earthquakes. **Giuseppe Amoruso, Polina Mironenko & Valentina Demarchi** propose a path of memory re–appropriation through multimedia installations, emphasizing the evocative interaction between reality, memory, and reproduction of the intangible to promote collective memory. Thus, the real environment becomes a temporary and experiential museum, expanding the immaterial dimension of accessibility discovery. Besides, **Caterina Palestini & Alessandro Basso** suggest a solution to promote the use of the historical buildings, activating at the same time the dynamics of cultural regeneration in the area, using AR+AI systems for a tour that can show the urban architectural evolution, monitoring and enhancing the knowledge and the transformations undergone by the architectural heritage.
Concerning urban routes, the experiential factor plays a central role. The experience occurs mainly through the human vision, which is dominant in AR/MR/VR development without excluding other senses. **Alessandra Pagliano** presents a project aiming at preserving the memory of murals using AR. In this way, the narrative message of the old murals is expanded thanks to the digital multimedia contents, reinforcing the storytelling, the cultural connection, and the memory of the place. On the other hand, **Fabio Bianconi, Marco Filippucci & Marco Seccaroni** suggest using EEG helmets synchronized to GPS to collect human cognitive conditions and transform them into representations that reflect the people's feelings during their itinerary. This research aims to define methodologies based on interdisciplinary interpretative criteria to understand the human–environment impact, directing design choices to improve wellbeing.
As mentioned earlier, large architectural spaces can be compared with those at urban scale, especially if the aim is to communicate and promote them through a more profound knowledge. This is the case of **Marco Canciani, Giovanna Spadafora, Mauro Saccone & Antonio Camassa**, who present two AR applications about important architectonic space, with the final aim to develop some AR multimedia content linked to semantic concepts. The proposed experiences use AR to share the analyses carried out on drawings and canvas, unveiling the constructive meaning of space.
The last cluster is dedicated to communication and promotion of local assets and retails, always framed through knowledge itineraries. **Paolo Belardi, Valeria Menchetelli, Giovanna Ramaccini, Margherita Maria Ristori & Camilla Sorignani** present the concept of "Augmented Retail," representing a strategy to achieve an Augmented Identity, changing the retail space from a 'product window' to an 'experiential theatre'. This research aims to open new perspectives based on AR and AI to enhance local identity promoting itineraries of historic shops. Regarding local assets, **Daniele Rossi & Federico O. Oppedisano**, illustrates the potential of AR in the valorization of food and wine heritage. They highlight the playful interactive capacities of this technology shifting towards renewed communication models that aim to extend the cultural offer in an increasingly rapid and immediate form.

AR&AI Museum Heritage

In the digital era, museums have seen a significant expansion of spaces and tools for the dissemination of knowledge. In this sense, the digital takes on multiple roles precisely articulating itself between AI and AR for new ways of disseminating and communicating Cultural Heritage. In this sense, **Massimo Barilla & Daniele Colistra** are involved in the creation of an immersive and interactive room – *Nello Scill'e Cariddi* – in which the marine environment of the

Strait of Messina is used as the first experimental scenarios to develop and test technology AI/AR. The room, therefore, transforms film collections, integrating them with the production of specific images, into virtual environments containing structured catalogs and into interactive installations for educational, playful, scientific and popular use. **Francesco Borella, Isabella Friso, Ludovica Galeazzo, Cosimo Monteleone & Elena Svalduz** then deal with the cultural interfaces that make a video installation which is also immersive and interactive. Their aim is to keep a high and active visitor's attention, in the video dedicated to the Academia insula of Venice several short–term sections have been introduced, which can be interrogated and activated by sensors, while a Sound Shower system facilitates the understanding of the multimedia story by listening to the voice of a storyteller. The contribution of **Laura Carlevaris, Marco Fasolo & Flavia Camagni** is also fundamental, dealing with the options provided by the recent applications of Augmented Reality (AR) to the knowledge and enhancement of a cultural asset: the perspective in wood inlays. The intention is therefore to use perspective in AR ambient as the ideal tool to virtually experience the space represented in the exhibited decoration. The creation of an experiential path linked to perspective, organized by a sensitive narrative that begins in the very act of its use, to allow the observer a critical interaction dependent on the process of knowledge of the works and their evoked spaces. This is what **Gabriella Liva & Massimiliano Ciammaichella** propose for the perspective analysis of some canvases by Jacopo Robusti. Furthermore, for the enhancement of Cultural Heritage it is important to explore the potential of the combined use of Augmented Reality (AR) and rapid prototyping. **Giuseppe D'Acunto** explores how these innovative methodologies can be effective in the creation of museum installations able not only to show the contents of an exhibition in an original and attractive way, but also to recover the memory of a place by reconstructing the original position of the environment, as in the case of the installation of Palazzo Grimani, where the sculptures have moved from their original position over the centuries. These aspects linked to the relationship between AR and VR for the installations are addressed by **Giuseppe Di Gregorio**, who highlights the workflow produced for the realization of the 3D models of one of the three churches in the rocks of the necropolis of Pantalica, an Unesco site. In this sense, the ongoing process to achieve the realization of VR and AR models to use with three different levels of immersive reality is important: normal commercial viewers, different types of Oculus viewers, or in special virtual rooms Cave Automatic Virtual Environment (CAVE). In this sense, the paper of **Elena Ippoliti** also deals with the research experiences of the last 15 years in which the potential of digital technology, and of Augmented Reality in particular, has been tested to enhance Cultural Heritage. This research outlines the value of preliminary digital simulation for form–finding, both in terms of the actual final configuration of the project and in terms of the less tangible aspects of the efficiency of building. As a result, representation takes on a new position as the 'place' of the model. The dynamic passage between real and virtual in a spatial model helps in representing intangibly, with high reliability, what is concretely abstract. The challenge of the use of Cultural Heritage by subjects with sensory limits has also become fundamental for museum installations. **Franco Prampolini, Dina Porpiglia & Antonio Gambino** propose the 3D survey of all the main finds to be exhibited with analytical photo–modeling techniques, their scientific cataloging, the creation of a website with a high interactivity content and an application that allows sharing extended information with blind people, through the combined use of analog 3D models and AR creation software. The topic of facial recognition technologies – already used today in many applications, to support security systems in sensitive buildings – is another developing theme for museums or art galleries. Indeed, **Paola Puma & Giuseppe Nicastro** describe an experimentation in a museum of a research in order to provide a tool capable of interpreting the reaction of a user in front of a work of art, proposing a responsive information content with what is manifested, through facial expressions. Finally, it is important to highlight how generative design is now fundamental for the creation of interactive digital configurations, aimed at the creation of artistic languages and for the representation of dynamic contexts. In this sense, **Leopoldo Repola, Nicola Scotto di Carlo, Andrea Maioli & Matteo Martignoni** have integrated a narrative process, linking aspects of recording the movement of bodies in water with the principles of data visualization.

AR&AI Building Information Modeling and Monitoring

AR & AI are currently playing an important role in the advanced implementation of BIM with special reference also to the monitoring of architectural and engineering artifacts. And there are many applications also in terms of Scan–to–BIM, such as the essay of **Vincenzo Bagnolo, Raffaele Argiolas & Nicola Paba** which present the first results of an ongoing research on the advantages of implementing computational modeling in Scan–to–BIM processes for the representation of historical architecture in AR and VR applications for educational and communication purposes. But if we consider that the conservation and regeneration of the existing built heritage is still characterized by an inefficient management of time and costs, throughout the life cycle, it is central the research proposed by **Marcello Balzani, Fabiana Raco & Manlio Montuori** which focus on the development of integrated digital solutions for the acquisition, modeling and visualization of data relating to the building and construction supply chain. At the same time **Fabrizio Banfi** highlights the convergence of innovative methods, latest generation of technologies and software applications for the representation, archiving, transmission of the material and immaterial values of architecture; for these reasons, he researches the development of a cloud–based open source BIM platform and XR/AI projects able of sharing a knowledge process based on new levels of interactivity and digital creativity. **Carlo Biagini, Ylenia Ricci & Irene Villoresi** also highlight how, in recent years, the application of BIM to Cultural Heritage has led to the development of solid operating methods that have enabled more efficient information management. They then tested whether BIM models can be exploited to create immersive experiences in digitally simulated environments, setting new ways of viewing and evaluating the built space. In this sense it is important to test the accuracy of the solutions adopted using BIM models, in a representation of the built structure that is also able to summarize the qualities to be detected. **Fabio Bianconi, Marco Filippucci & Giulia Pelliccia**, with their research, have developed some case studies in the field of wooden constructions, inserting themselves in a framework that emphasizes the relationship between simulation and realization. The introduction of automation methodologies through the use of deep learning of BIM modeling starting from different types of formats, such as digital processing of paper documents and CAD formats, is also important for the relationship between BIM and AI. In this sense, **David Campagnolo & Paolo Borin** emphasize as a proof of concept of a possible contribution that a technique currently barely adopted in the architectural field – such as deep learning – can lead to the design, in particular in the creation of the information model, an activity that today takes time. If we then consider that in the digital age the construction industry has seen significant changes in the design, construction and learning of spatial processes through new technological systems, it is important to highlight how these processes influence the management and the way in which data are collected, cataloged and monitored using sensors and connected users. **Matteo Del Giudice, Daniela De Luca & Anna Osello** therefore define new safe and resilient digital models combined with interoperable methods that minimize the impacts of our built heritage during its life cycle. In this direction we find the essay of **Raissa Garozzo** who proposes a new methodological approach for the evaluation of the health status of railway bridges in masonry based on the definition of image–based and AI–driven investigation protocols useful for the creation of semiautomatic H–BIM models. Similarly, the research of **Federico Mario La Russa** which provides an overview of the evolution of the VPL and an application case concerning the classification of seismic vulnerability indices with AI. An important topic involved in this volume regards also energy monitoring that can be implemented in an advanced way with BIM as in the research of **Marco Filippucci, Fabio Bianconi & Michela Meschini** who analyze, in particular, those buildings that, even if of different eras and construction technologies, require energy requalification. Finally, the contribution of **Assunta Pelliccio & Marco Saccucci** proposes a methodology (D.V.M.R., acronym for Design, Virtualization, Modeling, Reproduction), which in four temporally consequential phases builds a tool able of providing territorial, environmental, architectural and historical information of a particular case study (an industrial building) but extendable to the built heritage.

AR&AI Education and Shape Representation

A particular area of development of AR & AI could be certainly linked to educational purposes. Indeed, there are many repercussions that we can apply to students' training especially for aspects concerning inclusion and support. For example, the difficulties involving clinical autistics are mainly related to the perception deficit, therefore VR/AR & AI can become a valid support for people with ASD, improving relationships with space and people. **Anna Lisa Pecora**, in this sense, tries to provide a guiding tool for a human–centered VR design. So, at an academic level of education, AR & AI may facilitate the preparation in faculties such as Architecture and Engineering. For example, **Emanuela Lanzara & Mara Capone** propose how to improve a dataset of generative algorithmic definitions capable of returning an optimized "semi–ideal" curve that best fits a generic profile based on reality, starting from some of its points, with interesting effects in the field of education. Therefore, learning through the direct experimentation of "intelligent" models – in their variety of manifestations and hybridizations – is undoubtedly a very powerful aid in the acquisition of knowledge. This is what **Marta Salvatore, Leonardo Baglioni, Graziano Mario Valenti & Alessandro Martinelli** assert, entering into the specific role of the architectural configuration: testing or experimenting with models helps not only to understand the shape of existing architecture, but even more to imagine and design new buildings. In this sense, the essay proposed by **Roberta Spallone & Valerio Palma** presents methodologies, objectives and some of the results of a university course – Techniques of Digital Representation – in which the interaction between the different digital representation techniques in relation to AR and AI technologies is developed, providing tools for investigating critical aspects. Finally, it is important to underline the repercussions that training in these terms has for architecture, engineering and construction (AEC) industries: **Alberto Tono, Meher Shashwat Nigam, Stasya Fedorova, Amirhossein Ahmadnia & Cecilia Bolognesi** test algorithms for 3D reconstruction from a single image, specifically for building envelopes, with end–to–end geometric deep learning approaches. At the same time, the importance of this kind of apprenticeship can be recognized in the touristic industry, from a communication point of view, as **Maria Linda Falcidieno, Maria Elisabetta Ruggiero & Ruggiero Torti** affirm: their research introduces some insights and proposals shared with the operators of the sector and aimed at the intelligent reformulation of approaches and languages in order to bring potential customers closer to the Cruise Experience.

Notes

[1] Francesca Fatta is the actual president of UID (Unione Italiana del Disegno), an association that gathers all the Italian scholars of Representation.

Authors
Andrea Giordano, Dept. of Civil, Environmental and Architectural Engineering, University of Padua, andrea.giordano@unipd.it
Michele Russo, Dept. of History, Representation and Restoration of Architecture, Sapienza University of Rome, m.russo@uniroma1.it
Roberta Spallone, Dept. of Architecture and Design, Politecnico di Torino, roberta.spallone@polito.it

Isbn 9788835125280

AR&AI
theoretical concepts

The Role of Drawing in Data Analysis and Data Representation

Francesco Bergamo

Abstract

This paper discusses the role of Drawing in representing and designing new epistemological models during the current AI spread, especially in relation to new advanced tools available to scientists. The accelerated development of technologies for data visualization and immersive and augmented experiences consolidates shared workflows, while criticism and genealogies of such tools are too often left aside. Therefore, scholars have not only to develop new technological tools and applied methodologies but also to work on shared sets of theoretical concepts that are necessary foundations to designed contents. The history of representation – especially maps on one side, perspective on the other – provides most of the necessary common ground, which is much needed if we choose that it is still worth governing AIs as much as we can, instead of abandoning ourselves to 'the end of theory', which would imply the end of any meaningful scientific drawing made by and for humans.

Keywords
augmented reality, artificial intelligence, DataViz, heritage, interface design.

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"It's easy to forget that a lot of what we do as scientists comprises choosing how to represent our work. These choices are made not only for larger, public–facing events but also among ourselves at individual meetings, small conferences, and even in our emails. Ostensibly, in parallel, there's also the question of how much agency the scientist–qua–artist has over the work and its import" [1].

Immersive vs. Disembodied Representations

The many speakers and participants in the REAACH–ID Symposium showed several advanced applications of Augmented Reality and Artificial Intelligence in scientific research, especially in the fields of drawing and representation for cultural heritage and design, besides interdisciplinary exchanges aimed at building innovative tools for analyzing data and augmenting the user's experience while exploring information – be it for promoting or studying heritage, design approaches, etc.
A first rough classification of the theories and practices of representation, in relation to the new modes of production and communication of knowledge, would split common contemporary representational artifacts into two types, apparently antithetical. On the one side, immersive applications and interfaces, where perspective goes 'hyper' by taking the observer out of the frame of Alberti's window and into a virtual or augmented world. On the other, charts, maps, and diagrams, often looking much like traditional representations of networks: they are more and more non–perspectival, abstract, looking much like each other, their form more and more independent from that of the represented object, which often does not have a proper form itself (e.g., what does a pandemic 'look like'?).
The scientific bases of both types in the contemporary world can be found at the origins of the Modern era: the first coming from the western perspectival tradition [2] and the second from cartography but also from the many attempts to represent abstract theories or ideas – and their underlying systems of relations – onto schemes of growing complexity. The two paths are apparently disconnected, but they often draw from the same knowledge (the progress of geometry, optics, etc.) and sometimes they cross in 'places' such as, for example, memory theatres and, as it will be proposed at the end of this paper, potentially elsewhere today.

Theoretical and Representational Issues

The critical and theoretical literature on both of the aforementioned paths is growing [3]; but while the first takes advantage of its many connections with media studies [Grau 2003; Zucconi 2018, pp. 149-181], the second is still struggling to find its roots mostly on marginal grounds [Facchetti 2019]: despite the fact that we are more and more exposed daily to infographics and data visualizations when it comes to AI [D'Abbraccio, Facchetti 2021], we inevitably face the irrepresentable. Even our interaction with Internet and computers often appears mysterious, their responses being ruled by apparent randomness or by non–human wills. In our era, characterised by the availability of large amounts of data, machines, and algorithms capable of correlating them, one can easily yield to the temptation of proclaiming "the end of theory" [Anderson 2008] and give up building models that cannot compete with the ostensible objectivity of data and machinic intelligence. For instance, Google Translate has been using since 2016 a neural network developed by Google Brain to replace the previous statistical inference model. No more cross–references of texts, but a real intelligence: "not a set of two–dimensional connections between words, but a map of the entire territory […]. The map is thus multidimensional, extending in more directions than the human mind can hold. As one Google engineer commented, when pursued by a journalist for an image of such a system, "I do not generally like trying to visualize thousand–dimensional vectors in three–dimensional space. This is the unseeable space in which machine learning makes its meaning" [Bridle 2018, p. 148].
Yet we are very aware of how much we need visual representations of complex phenomena per se and how much we need them to rule those phenomena. During the first stag-

es of the Covid–19 pandemic we behaved according to the imperative of 'flattening the curve', where 'the curve' was a graph looking like two Gaussians, one without protective measure, the other – smoother, contained under the 'Healthcare system capacity' line – with. And even though with AIs and Big Data the (unrepresentable) maps tend more and more to coincide with the (inaccessible) territories, the Event Horizon Telescope team spent years and deployed huge resources to process a static bidimensional image of the black hole at the centre of the Messier 87 galaxy, which became viral on social media just a few hours after it was released, on 10 April 2019 [4]. It succeeded largely because it looked like a photography.
These questions are crucial for many scientific disciplines, and the problematic folds of their unknown lands are calling for scholars of Drawing to act on the bases of their own knowledge. Consider the pandemic graphs and maps [5]: the more data speak clearly through their representations, the more they are insidious, to the point that they can be interpreted in totally opposite ways or confuted based on one or more steps during the phases of collection, sifting and visualization. In most cases, paradoxically, the representations that are more difficult to understand and decipher are also the most engaging for those who want to understand them in depth, because they force the viewer to activate a sort of critical awareness: they may not be adequate for quickly comparing trends – such as economic growth or the number of infections – but they work because they force us to pay attention to what is underneath. Common experience also shows that much of the work that careful use of these artifacts has to do, to find a thread to follow in such opacity, is in the reading of the texts that accompany visualizations, commonly found in scientific papers as well as in newspapers and magazines. Texts commenting visualizations are fundamental to understand and evaluate the choices made by scientists and/or infographic designers.

Drawing at the Intersection of Digital Humanities and Human Digitalities

The role of humanistic knowledge, therefore should be upgraded in data analysis and representation. Recently, the writer Helen Dewitt and the statistician Andrew Gelman published a short piece together [Dewitt, Gelman 2020] where they addressed the problem of what we could call 'DataViz criticism' [6]. The article refers especially to the proliferation of data visualizations at the time of the Covid–19 pandemic, to their potential and real "narrative" implications and to the lack of attention given by designers to the possible uses of such graphic artifacts. The two authors begin by comparing an old diagram drawn by Florence Nightingale on the causes of mortality during the Crimean War (1853-56) with a contemporary analogous and much simpler diagram, highlighting how the first is more difficult to read but also more 'engaging' for the reader, more suitable for drawing her to a critical–narrative dimension.
The role of Drawing, between technical and humanistic knowledge, can be therefore strategic non only when it comes to representing, but also for the structural and infrastructural configuration of the digital clones of reality, or 'digital twins', that are becoming bigger and more and more integrated with each other and with everyday life through interfaces and algorithms, and that are based upon data collected and processed by means of optical–perspectival devices. These data are getting more and more important to integrate and augment reality with synthetic information, which is provided by optical sensors, algorithmic observers and artificial intelligences. If a giant tech corporation should ever monopolize the database of worldwide real time optical scans, it would lead to a sort of diffused global panopticon of enormous power, controlling AR games, self–driving vehicles but also much more [Kelly 2019]. And this is just basically the same technology that scholars use when surveying a piece of cultural heritage to obtain a digital twin to preserve it, to promote it, to study it in detail, to plan and design possible interventions, etc.
Here is why Drawing must face the challenge not only to represent, but also to define and take part in the construction of new epistemological models: confronting the unfathomable complexity of AIs demands for new tools to build shared models and govern reality.

The alternative is to give up models and representations, to abandon science at the end of theory, to mere correlation among data [7]. Scholars are involved because they are familiar not only with technologies and workflows, but also with the optical, perspectival, geometrical and, more generally, representational knowledge that lies underneath, which is to say: with the very roots of the systems, infrastructures and interfaces that are shaping today's human interactions with the world.

Between Perception and Scientific Analysis: Metaphors and –scapes

As human beings, we probably need conceptual tools such as metaphors to deal with complexity [Bridle 2018, pp. 2-10]: after all, it's exactly what we do every time we use a desktop computer, open a folder, and edit a file. Today's systems of power are often described by and modelled upon scopic regimes, as we have said about the potential of the digital twin of the world [Kelly 2019] and as we know very well from Michel Foucault [Foucault 1975], Martin Jay [Jay 1988] and the last episode of Adam Curtis' documentary series Can't Get You Out of My Head (BBC 2021). In fact, we are used to find metaphors coming from optics almost everywhere: transparency is a myth of modernist architecture as well as of interaction designers [8], but we claim it also from finance, economy, politics, at every scale. Catoptrics has been used by post–modernists to critique Modernism's faith in transparency and to subvert it. And dioptrics may provide useful references to better understand and design today's world with a critical attitude [Bergamo 2019], together with other optical notions such as, for example, that of parallax [Anderson 2018].
It is up to Drawing also the ambitious and relevant task of connecting and interweaving the paths of the two big categories with which this paper began: god eye's maps and human eye's perspectival views. Some of the possible meeting points can be found in '–scapes'. Not only in the much–debated notion of landscape, which after von Humboldt merges the subjective perception of the observer with scientific collection and observation of information [Farinelli 2003, pp. 40-53]. But also, for example, in the many possible representations of soundscapes [Bergamo 2018] and in sound maps, which should start addressing the problem of placing perspectival and time–dependent audio field recordings onto interactive visual maps. And in datascapes, researched in the Nineties by the artistic collective Knowbotic Research and today by Ryoji Ikeda: abstract visualizations of digital data become a sort of artificial immersive landscape, engaging the viewer and, at the same time, potentially providing her with new visual metaphors, new tools to represent what exists and design what will come.

Conclusions

Technology has evolved, the world has changed, but we are still the same species that tried to visualize and organize such a complex thing like memory in machines that worked like modern theatres, after all.
Drawing always played a major role in modeling knowledge. This paper tried to explain why the technical achievements it is deploying while facing the current challenges should be connected with the historical and critical background provided by the genealogies of perspective and maps: this much needed approach could lead to innovation in representation in today's world, and it is up to the Drawing scholar.

Notes

[1] George Wong in Frumkin Rebekah (2019). What the Scientists Who Photographed the Black Hole Like to Read. In The Paris Review online edition, www.theparisreview.org, (10 March 2021).

[2] We could think about Paolo Veronese's frescoes at Palladio's Villa Barbaro as pictorial devices to "augment" the architectural experience of the owner and inhabitant and to "immerse" him in a virtual extension of the outer landscape, but the genealogy of this approach could go back in time much more, passing through Pompeii and up to cave paintings.

[3] A book about the genealogies of both is e.g. Arcagni 2018.

[4] See https://eventhorizontelescope.org/press-release-april-10-2019-astronomers-capture-first-image-black-hole (10 March 2021).

[5] Some media designed their own, as in the case of The New York Times; others, the most, drew from renowned research institutions; expert users could also rely on more sophisticated online tools that allow to compare and filter data according to the answers they needed to retrieve. See https://ourworldindata.org/coronavirus (10 March 2021).

[6] This phrase is not found on their article, but I think that it describes in synthesis what is at stake here.

[7] Which may lead to aberrations, such as nonsense and funny correlations between the number of people who drowned falling into a pool and the films Nicolas Cage appeared in. See the website Spurious Correlations: http://www.tylervigen.com/spurious-correlations (10 March 2021).

[8] A good interface is one the user doesn't realize it's there, according to most and especially after Donald Norman. See Norman Donald (1998). The Invisible Computer. Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances Are the Solution. Cambridge (Mass.): The MIT Press.

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Author
Francesco Bergamo, Dept. of Culture del Progetto, Iuav University of Venice, fraberg@iuav.it

Isbn 9788835125280

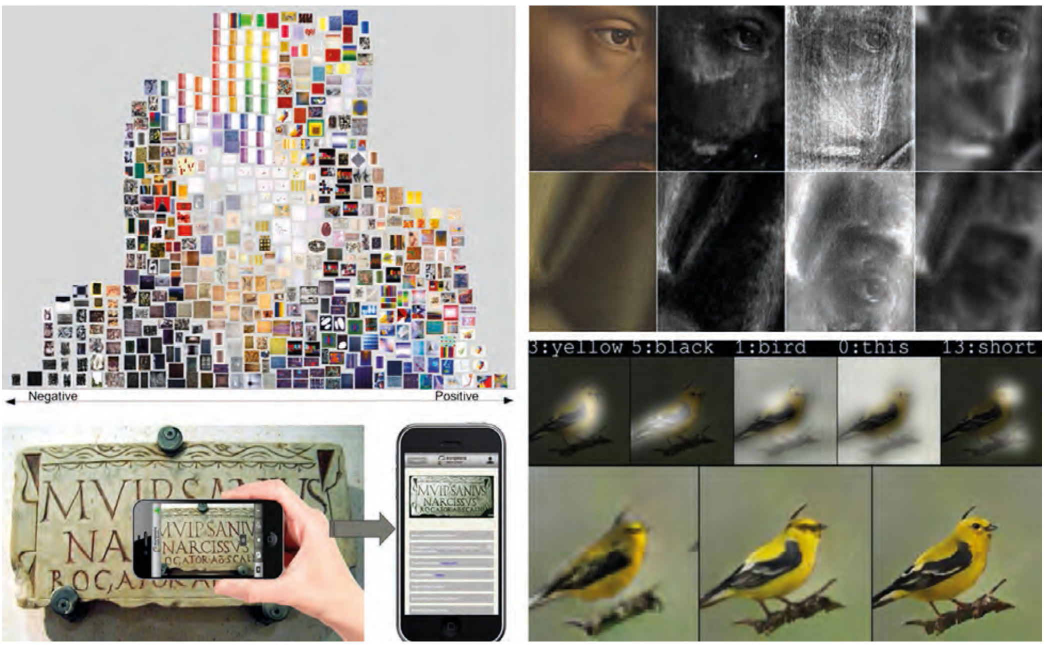
Artificial Intelligency, Big Data and Cultural Heritage

Giorgio Buratti
Sara Conte
Michela Rossi

Abstract

In recent decades, the cultural heritage sector has benefited from solutions offered by ICT for the conservation, management, enhancement and communication of cultural heritage; today this specific sector benefits from the infinite potential of application of AI. The proposed research identifies the three main lines of research that operate in the cultural heritage exploiting the synergy between machine learning, big data and AI, starting from the analysis of the state of the art and a subsequent first taxonomic approximation of artificial intelligence systems. The analysis of some case studies developed in the field of recovery and restoration of cultural heritage, monitoring and prevention of damage, data acquisition and analysis of the same, confirm the real potential of AI: trigger knowledge from knowledge.

Keywords
AI, cultural heritage, interaction, automatic drawing, taxonomy.



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Introduction

Since the 2000s, the improvement in microchips' computing performance has made creating, collecting and transmitting data so fast and cheap, to bring the amount of available information to exceed a crucial threshold [1], determining the advent of the so–called Big Data era. Originally, the term "Big Data" referred to the technical ability to collect, store and process increasing amounts of data at decreasing costs. There is nothing innovative about this definition, which could be compared to the advantages of printing over handwriting or any other technical improvement in cultural technologies history. The unprecedented aspect is the ease of accessing more data than it seems possible to handle for the first time in human history data is abundant and cheap and continues to exponentially increase. The information collected in digital form in a delocalized telecommunications network is accessible in real time to various types of electronic devices that allow data re–processing. In this context, any search creates in a few seconds a redundant mass of information that complicates the identification of the most significant content. The quantity and type of information has reached a complexity that transcends a direct management possibility, requiring an adaptation of the taxonomic ordering structures used up to now to understand phenomenal reality and to manage knowledge.

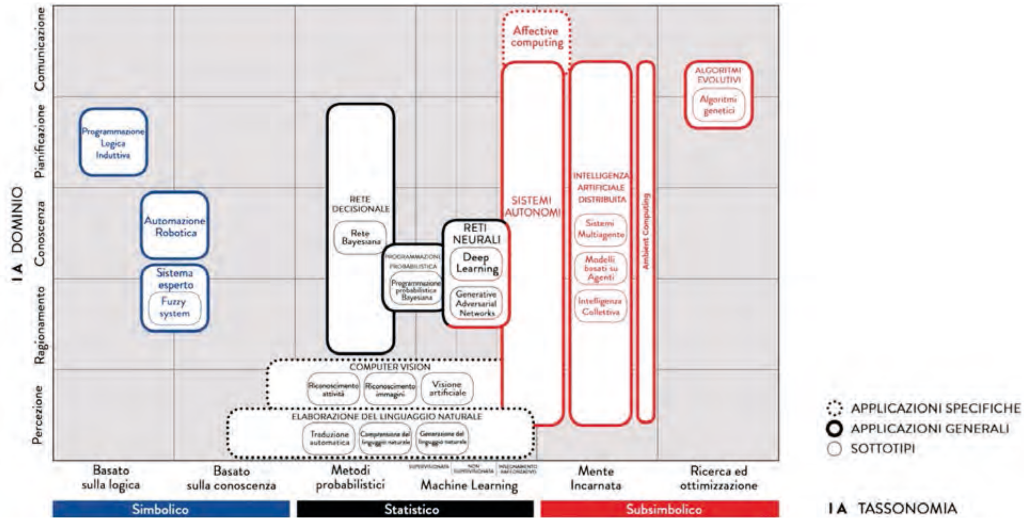

Fig. 1. Taxonomy of Ai referred to F. Corea, https://www.kdnuggets.com

AI and Big Data: Order Complexity

Unlike humans, computers can use the growing amount of 'disordered' information by defining a new way of producing knowledge, no longer based on reference theories, but on a posteriori identification of recurring patterns within the rough data flow. This abdication of the causal logic linked to reasoning in favor of computational analysis does not imply a 'technological' determinism or that data driven research must guide all cognitive processes, because the data has no intrinsic value but in a defined context. If knowledge's inferential processes start from the informations acquired, it's also true that a simple data accumulation does not generate knowledge without a method capable of identifying the correlations among variables. In this context becomes crucial research on Artificial Intelligence, a definition that includes a differentiated set of techniques and methods with the aim of automating human cognitive abilities. And since computers process data at speeds now close to the speed of light [2], it is possible to analyze increasing amounts of information, generating predictive models based on objective assessments. Since its inception, AI research focuses on the creation of models that simulate the dynamics of human intelligence, based on the comparison and reworking of external stimuli, which can be classified according to the main active research directions. The table (fig. 1) shows on ordinate axis the abilities of human intelligence:

• Perception: skill to transform sensory inputs into useful information);
• Reasoning: skill to connect / solve problems;
• Communication: ability to elaborate a language and transmit concepts;
• Knowledge: skill to understand and represent reality;
• Planning:skill to define and achieve objectives.

The main research lines currently recognized are summarized on the abscissa axis:

• Symbolic Approach: which considers intelligence as that process of transforming perceptual stimuli into symbols to which a meaning can be attributed, according to more or less formal rules;
• Statistical Approach: based on logical–mathematical tools to extract information content useful for transforming information into knowledge starting from Bayesian inference, formalizing the hypothesis that a greater use of a given data increases the probability of its exactness;
• Sub–Symbolic Approach: based on neuronal functioning whereby information is transmitted regardless of meanings: knowledge emerges regardless of previous mental models, but on the basis of structures based on experience.

From these line of research, six subgroups descend which identify the main AI applications:

• Logic–based: tools used for problem solving through the orderly representation of knowledge;
• *Knowledge–based*: tools with extended ontologies and relational databases of notions, information and rules;
• Probabilistic Methods: tools that allow agents to act even in incomplete information scenarios;
• Machine Learning: tools that generate data from other data;
• Embodied Intelligence: engineering toolbox, which assumes that a body (or at least a partial set of functions such as movement, perception, interaction, and visualization) is required for higher intelligence
• Research and Optimization: predictive calculation tools that allow you to optimize possible solutions according to the specific context.

These methods are already used, often unknowingly, on a daily basis: when we ask for directions to our portable device or ask a virtual assistant to turn on the light, we are interacting with natural language interpretation AI and neural networks trained to carry out research and home automation operations.

For some years now, the use of genetic or evolutionary algorithms in form finding studies has consolidated the AI tools also in the drawing discipline. These processes consider the different morphological hypotheses as biological individuals and recombine them, similarly to sexual biological reproduction, introducing elements of disorder that simulate random genetic mutations.

Thousands of formal solutions (new individuals) are thus generated, among which those that guarantee the highest level of optimization are chosen, just as selective processes promote the survival of the individuals most suitable for an ecosystem. In this way it is possible to explore solutions hitherto unused due to the lack of description and control tools adequate to the problem complexity.

The New Frontiers of AI Applied to Cultural Heritage

The first one collects all the research characterized by the development of innovative methodologies and systems to monitor and prevent damage to the cultural heritage, helping to increase the offer for the users. The most common example is the biosensor that can prevent damage from biological pests. This is any analog or digital device that works with living organisms (indicators) able to respond to certain environmental stimuli, producing an electro–chemical, optical signal to reach a threshold value. Today automatic biosensors are studied, that work in real time and continuously to signal in indoor environments the achievement of favorable conditions to germinative factors and therefore a constant monitoring of the state of health of the good [Danese et al. 2019]. Significant are the researches based on the use of neural networks in conservative perspective; in particular the one carry on by the researchers of National Gallery, Duke University and University College of London, that used neural networks to analyze complex high–resolution digital X–ray images of the cathedral of Gand "Adoration of the Mystical Lamb" [Van der Snickt et al. 2020]. Convolutional neural networks (CNN) combined with multi–resolution imaging techniques, initially used to determine the

authorship of a work and to distinguish fakes, are now able to reconstruct unfinished or deteriorated drawings from time as demonstrated by the research of the Dutch Technical University of Delft [Zeng et al. 2019]. The goal is the automatic reconstruction, through a pixel wise technology, of Vincent van Gogh's drawings that are deteriorated by time. The team was able to return works now irretrievably lost to the public, using the algorithm inspired by biological neural networks similar to human brain ones and trained on a data set containing reproductions of original drawings of various qualities, sizes, made at different times.
The second area analyses the experiments that focus on automatic data acquisition, such as the application of mobile technologies for three–dimensional surveying and the acquisition of images of monuments, architectures, archaeological sites. The distributed AI is an interesting line of research that is giving the first results in the field of three–dimensional and photogrammetric relief, through drones that are able to direct their flight in strategies similar to the ones of bees and other social insects. Flight trajectories are not pre–programmed for individual units, but depend on the network of interactions given by the continuous communication between the various subjects, and between them and the environment in which they operate, as it is visible in the Aerial Construction project [Willmann et al. 2008]. The project of the DISI of the University of Trento in collaboration with local authorities, such as the MART of Rovereto goes further, developing AI able to analyze the influence on perceptive properties and the emotional level that a work of art arouses in the observer. The AI recognizes the intensity and the type of the emotion through a facial recognition system based on the affective computing and the deep learning, providing useful information for the museum and curators [Sartori et al. 2016]. The work of the CNR–IMATI within the project Horizone 2020, GRAVITATE provides us an example of automatic extraction of features through the Generative adversarial network. The experimentation allows to identify the ceramic fragments, through the combination of semantic and geometric elements, and to assemble them in a semi–automatic way, simplifying the work of the archaeologist and giving the possibility to virtually reunify a spread archaeological heritage. [Moscoso Thompson, Biasotti 2019].
The third field aims to develop systems for the management of large amounts of data and informations, analog or digital, contained in libraries, archives, museums, and to provide the user with easier and more immediate access to information. There are many apps today that want to meet the needs of the users, who are visiting cities and monuments, by providing in real time useful and richer content and interpretations of our past, mainly using the ambient computing and the deep learning. Time Machine is a European project that aims at 4D digital reconstruction of every historical place of the main European cities, combining them with data of all types accessible with augmented reality interfaces; Monugram allows to give information of a monument based on the recognition of the image taken by the user in real time; Woolysses is an interactive chatbot for tours enriched with personalized multimedia content and anticipating the needs of the user; Eagle, allows automatic recognition of Greek/Latin epigraphs and dissemination of associated information. The aim of the different methodologies is unambiguous: to orient the technology towards the rediscovery of the knowledge to protect it or make it accessible, putting the digital reality at the service of the material one.

Conclusion

The fields of application of AI are constantly evolving and searching for new contexts in which the application of predictive algorithms allows the extrapolation of finalized solutions from the automatic reprocessing of a large amount of data. The intelligence of the machine is a consequence of the research speed of comparable information in a network that mimics neural connections. The solution is the statistical result of a comparison based on the evidence: a digital reinvention of the empiricism that preceded the development of experimental science, which built knowledge on reasoning aided by intuition. New knowledge is born from the empirical reworking of previous knowledge; the added value is parametric definition of reworking and the relationships between algorithms, controlled by humans. The inventiveness that distinguishes it does not depend only on logical capabilities; in fact the

described context opens to a series of reflections within the transformations taking place in drawing and in the contribution of the machine to design.
For example, the Drawing–Bot is an AI developed by Microsoft in collaboration with three American universities that uses the technology of the antagonistic generative network to create images from its description. A neural generative network creates new images from some keywords, while an antagonistic network compares them with a database of existing images, eliminating the results that differ from it. At present this AI produces good results for short and explanatory expressions; it is able to easily extract the forms and then integrates them autonomously with the absent details from the given description, while the final result is likely to be a confused image for complex descriptions, but it is only a matter of time and speed of calculation. In the example [Zhang et al. 2017] the quality of the representation is close to the photographic one, but the reproduced bird does not exist in the reality, is a representation born from the "imagination" of a computer. This case opens up to a series of reflections on the machine's learning potential and on how the relationship between the machine and the designer may evolve in the future. Today the machine is able to create a drawing based on the same geometric rules used to trace it by hand, but will it be possible to teach the machine the capacity of autonomous reasoning and to simulate the human creative capacity, through data processing?

Notes

[1] At the time of writing [2021] the amount of data currently engaged in the world each year is about 40 ZB [zettabytes]. One ZB corresponds to 102121 bytes, equivalent to approximately 180 million times the information collected in the records kept in the Library of Congress in Washington, recognized as the largest existing library with over 158 million documents held.

[2] At the time of writing, the most powerful computer in the world is Summit, developed by IBM for the ORNL, United States Department of Energy, capable of handling 100 petaflops, equivalent to 100 million billion operations per second. Summit is used in studies ranging from particle physics to weather/climate forecasts, from the creation of new drugs to the simulation of the effects of nuclear explosions.

[3] Although the paper was conceived jointly, Michela Rossi is the author of *Introduction*, Gorgio Buratti is the author of *AI and Big Data: Order complexity* and the related image, Sara Conte is the author of *The new frontiers of AI applied to cultural heritage*. The *Conclusions* are drafted jointly.

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Authors
Giorgio Buratti, Dept. of Design, Politecnico di Milano, giorgio.buratti@polimi.it
Sara Conte, Dept. of Design, Politecnico di Milano, sara.conte@polimi.it
Michela Rossi, Dept. of Design, Politecnico di Milano, michela.rossi@polimi.it

 Isbn 9788835125280

Virtual Tours and Representations of Cultural Heritage: Ethical Issues

Marco Ferrari
Lodovica Valetti

Abstract

Nowadays museums realities are increasingly interested in introducing advanced technological tools, in order to preserve and enhance the Cultural Heritage, as well as to make it more accessible and attractive. In fact, digital tools, such as Virtual Reality (VR) and Augmented Reality (AR), allow to provide effective responses to the needs of different types of users, to enhance the expressive qualities of the cultural asset, as well as to enrich the visitor's learning possibilities. However, the integration of new technologies in the management of Cultural Heritage involves different type of ethical issues. The paper analyses some of the ethical issues related to ontological, economic, and social aspects, trying to outline some principles able to limit these critical implications.

Keywords
museums, ethical issues, accessibility, virtual reality, augmented reality.

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Introduction: the Digital Fruition of the Cultural Heritage

The contemporary indications concerning the protection and the enhancement of the Cultural Heritage promote the overcoming of the passive protection principles. Currently the insertion of purposes linked to the fruition and expansion of the communicative potential of the goods towards a wide and heterogeneous public are being promoted. As a consequence, in the last years innovative strategies have been introduced in the field of Cultural Heritage aimed at blending digital techniques and technological tools with conservation and enhancement strategies. The combination 'technological innovation – Cultural Heritage' opens new scenarios and requires the development of innovative approaches in the management of the Cultural Heritage. Within this frame, this paper investigates the application of Augmented Reality and Virtual Reality tools in historic sites and museums, considering the consequent ethical issues that this application involves.

Nowadays the accessibility and the correct communication of the Cultural Heritage are considered fundamental aspects of the enhancement strategies, aimed at making the cultural assets accessible to as many users as possible. One of the main approaches, applied in order to increase the involvement of the public, is the introduction in the field of Cultural Heritage of advanced digital technologies [Carrozzino, Bergamasco 2010, p. 452]. In fact, the enrichment of the tour experience in historical, archaeological and museum sites, combining traditional communication channels with new digital systems, based on multimedia contents (audio, video, hypertext, and/or three dimensionsal digital environments), is becoming increasingly popular [Orlandi et al. 2014]. These strategies allow to provide effective responses to the needs of different types of users, to facilitate the enjoyment of the cultural assets, to enhance their expressive qualities, as well as to enrich the visitor's learning possibilities. In other words, new digital systems could contribute to the enhancement of the Cultural Heritage and its context, promoting its cultural and touristic values.

Currently, two of the most widespread technologies applied in the field of Cultural Heritage are the Virtual Reality (VR) and the Augmented Reality (AR). VR and AR are visual (the image is the centre of the communication) and interactive technologies (the active intervention of the users is required), which are characterized by providing immersive and interactive experiences. The introduction of these digital tools involves a change in the traditional learning process, no longer based on passive interaction, but rather on the active participation of users [Carrozzino & Bergamasco 2010, p. 453]. In particular, Virtual Reality (VR) consists in the use of a computer technology that allows the virtual reconstruction of imaginary or historical sites (such as cities or sites belonging to past eras and no longer existing). Thanks to the application of VR, it is possible to create reconstructions that allow the visitor to visually perceive a site and its changes over time, as well as settings belonging to past eras. In a VR environment, users can have the perception of being totally immersed in an artificial world, interacting actively with it [Carrozzino & Bergamasco 2010, p. 453] [Styliani et al. 2009, pp. 522-523]. A virtual reconstruction, if properly realized, can bring educational, historical, and scientific values.

In addition to VR exhibitions, nowadays also the use of Augmented Reality (AR) is growing. AR is a technology that allows to add digital contents to real exhibition scenarios, enriching the communication. The virtual information (i.e. 3d objects, as well as any type of multimedia information, such as textual or pictorial data) is overplayed upon a video frames captured by a camera, giving the users the impression that the virtual cultural artefacts actually exist in the real environment [Styliani et al. 2009, p. 523].

The introduction of these kinds of technologies could have different purposes. First, they could supply a significant contribution in improving the communication. The tour experiences in historical, archaeological and museum sites could be enriched thanks to the introduction of multimedia contents, able to implement the visitor's learning possibilities through immersive experiences. The introduction of these technologies can be a way to increase the amount and the quality of information and to differentiate them by age and specific interests. The creation of innovative and amazing scenography (i.e. 3d reconstructions) and the introduction of dynamic information transmission systems [Vaudetti et al. 2013, p. 95] could allow to increase the attractiveness the cultural goods for a wide audience, even non–specialists.

In addition to the communicative one, there are other purposes, equally important. In some cases, the virtual reconstruction of the Cultural Heritage could allow the virtual access of spaces that currently cannot be opened to the public for security or conservation needs. Within this frame, the intervention would also be a trace of a contemporary operation on the heritage, in compliance with the restoration's guidelines of compatibility and minimal intervention. Furthermore, the need to preserve the historical–artistic memory of Cultural Heritage, constantly subject to degradation phenomena caused by natural and anthropic events (wars, terrorist attacks, etc.), is ever more urgent [Orlandi et al. 2014]. The digitalization of Cultural Heritage could be an opportunity for passing on historical memory to future generations. Moreover, the life cycle of Cultural Heritage could be extended by limiting the accessibility to the sites and promoting exclusively (or partially) their digital use.

Ethical Issues

As seen, the use of VR and AR, as tools for the protection, development, knowledge, and fruition of Cultural Heritage, on one hand, achieves numerous goals, collecting wide interest and success of the public; on the other hand, it raises some ethical questions, mainly related to the ontological, economic and social sphere.

The first question concerns authenticity. In the context of the reconstruction through VR and AR of a setting (fig. 1), a monument, or an archaeological object, we must ask ourselves about the authenticity of reproduction. In the case of virtual restitution of an object or a context that presents multiple gaps, the result irremediably presents a character of subjectivity, although the choices can be supported undoubtedly by an in–depth historical and scientific investigation. The outcome is the product of a univocal interpretation of the past through one of the many possibilities of analysis. In a try to bring the visitor closer to an in–depth knowledge of an object, in reverse, there is the risk of turning it away from the original, devaluing its value [Styliani et al. 2009, p. 525]. Therefore, the boundary between reality and fiction arises as to the main theme in VR and AR use. The informative and playful dimension must not risk compromising the authenticity of the work.

Secondly, we must ask about the economic feature of this technology. Design, configuration, and maintenance of VR and AR systems usually have very high costs; their use often requires large spaces dedicated, and qualified personnel who take care of their operation and use by the public. Therefore, it is an instrument in the economic possibilities of wealthy museum realities, able to sustain the technological investment; realities already

Fig. 1. Recostructive proposal of the amphitheatre of Lecce. A frame of narrative approach – DiCet project [Gabellone 2015].

started and recognized, which – through their revenues or the support of patrons – implement the development of a heritage that may already be widely known, promoting its fruition in an innovative, diversified, modern, and endearing way. In the case of small, less fortunate museums, with reduced spaces and limited resources, the adoption of this technology, for example, would make accessible more objects normally not exposed due to lack of space, as well as it would offer more attractive visiting ways, welcoming broad public interest and obtaining profit and sustenance. An economic gap emerges in the potential of these instruments: they are promoted by already virtuous realities and hardly available to others that would need them to promote themselves.
Finally, a delicate question about social context arises. On one hand, the VR and AR use is extremely inclusive, providing opportunities to people with special needs (visual, acoustic, vocal, motor disabilities, and learning difficulties); however, on the other hand, the devices currently in use allow a type of visit characterized by a strong individualism. The isolation in the experience, often combined with the absence of a guide, can entail a loss of interest by the user: the deprivation of a stimulating relational exchange – between visitors or with an expert guide – risks to reduce the educational value of the contents offered as well as the indispensable emotional dimension, despite the strong visual impact of the context. Moreover, the growing diffusion and application of these technologies in daily and domestic life, from cinema to videogames, implying the possibility of seeing without imagining, can induce an estrangement of the user from the essence and the purpose of the experience itself: the significance of the artwork, the scientific value of the reconstruction, the informative and didactic goal. Therefore, we witness the feared «Guggenheim effect» [Carrozzino & Bergamasco 2010, p. 457]: the fascination of the container overcomes and reduce the content, transforming the experience into mere entertainment rather than an opportunity to transmit information.

Conclusions: Principles for Alternative Scenarios

The use of these technologies, therefore, entails great advantages but also raises questions that lead us to reflect on principles able to limit their critical implications.
Firstly, the sources on which to build the virtual reading of the Cultural Property must be undeniable, as a guarantee and protection of its values of authenticity and uniqueness.
Secondly, from the point of view of communication, technology must act as a means of knowledge and culture, not as a mere attraction in order to implement tourist and economic flows. The main purpose should be the communication of historical, artistic, and cultural values of a population, as well as the authenticity and uniqueness of a work. Therefore, it is necessary a deep awareness based on education and culture: both on the part of the developers towards the contents to be communicated, and on the part of the users towards the added value that augmented reality offers. VR and AR are also instruments whose use must be calibrated and measured on the monument itself; cultural heritage institutions must assess their actual necessity and usefulness.
Concerning the economic gap that underlies the possibilities of each museum, we have to reconsider the criteria for access to funding and redefine the distribution of resources for the design and development of these technologies. In this way, less fortunate museums could benefit from funding for the conservation and enhancement of their heritage, provided that the proposals to be financed are examined by a multidisciplinary scientific committee that controls the methodological validity and the ethical implications.
Finally, technological development must increasingly be directed towards collective inclusiveness, preferring opportunities for comparison and evolving from the individual dimension. The correct communication of scientific contents must be guaranteed through the interaction with a guide or through the presence of an interface that can offer support for the visit, hoping that the technological innovation may soon lead to social and increasingly inclusive use.
In conclusion, VR and AR represent interesting tools to share knowledge, conservation, and development of the values of Cultural Heritage, provided that both their planning and fru-

ition are based on awareness and respect for uniqueness, materiality, and cultural, historical, and artistic values. There must be rules that control their use informing users that these technologies are not games: they share contents and information of high cultural value. The relationship between man and machine and the concepts of real and virtual must be kept at the center of innovation and application in this field. The many opportunities and risks impose that society negotiates the uses of these technologies, guided and supported by a coherent philosophical approach [Arcagni 2016]. In this way, these tools will become part of a historical moment and will represent a cultural value of our century to be handed down.

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Authors
Marco Ferrari, Dept. of Architecture and Design, Politecnico di Torino, marco_ferrari@polito.it
Lodovica Valetti, Dept. of Energy "Galileo Ferraris", Politecnico di Torino, lodovica.valetti@polito.it

Isbn 9788835125280

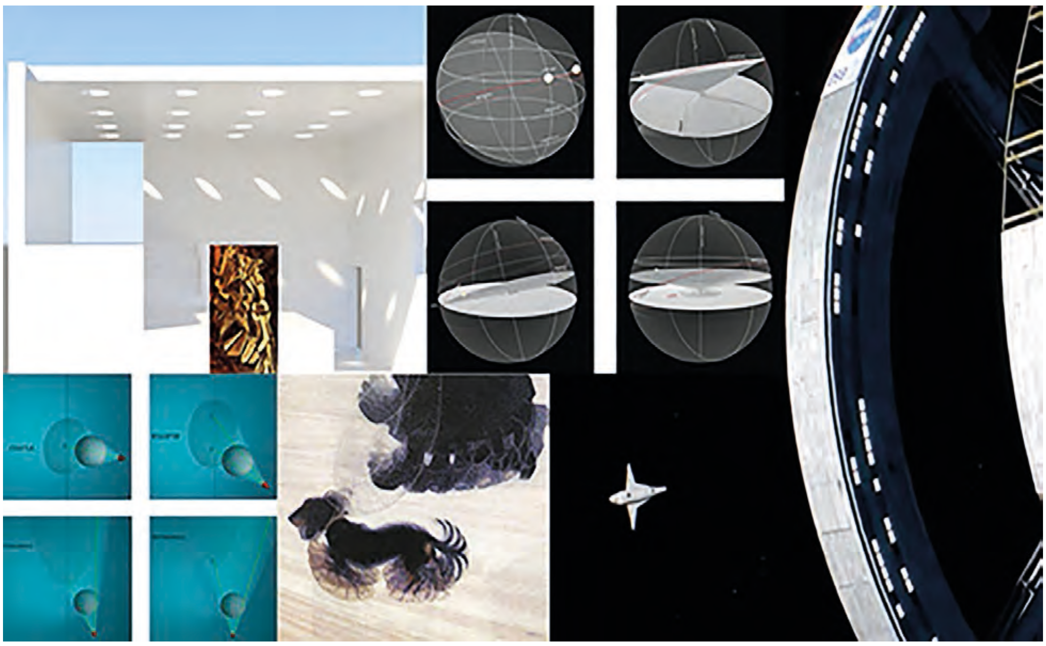
The Magnificent AI & AR Combinations: Limits? Gorgeous Imperfections!

Claudio Marchese
Antonino Nastasi

Abstract

Time and Space persist, in the digital age, as coordinates in which human presence is located. We will analyze some forms in which it is demonstrated "scenarios" concerning: a) spatial prefigurations of human 'refuges'; a transition place between external and internal. Phenomenology experienced, in moving through the atrium of Alberto Campo Baeza's school in Loeches, crossed by the pupils. Movements punctuated, in opposite directions, by natural light variations and related shadows that continuously reconfigure it. AR b) measurements, regarding the astral motion of a satellite and shadow creations, revealed through light features. Variations defining the possibility in measuring time, due to three "bodies", one that illuminates, another that is illuminated, and an intermediate one, receiving the shadow. c) relationships, where Exalt and Hologram, evoke in AR sequences the preservation of species, in which we are already protagonist, and in '2001: A Space Odyssey', struggling with AI.

Keywords
prefigurations, measurements, relationships, space, time.



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Prefigurations

When Giedion published his 'Space, Time and Architecture', it was sanctioned the intrinsic Architectural relationship with the two vital components, space and time, in which the human presence is sited in the world. Humanity becomes aware of itself, as well as in the form of relationships between individuals of the same species and as well with other subjects, animate and inanimate that constitute the living environment in which one moves, measured through his proportions: this we call Space.
Space, a stable entity, yet varying within the time ordinate, was somewhat immediately revealed to man through its cyclical manifestations. Day and night sequences taught man the art of prefiguration, making him feel set in and even cable in forecasting. Prefiguring desired events, essential for man's existence, brought him to draw on the walls of his first abode caves, essential sketches representing the phase sequences of hunting and gathering food. With this, man is affirmed as a species capable in elaborating paths going from aspiration to the realization of the event. Didactics, initiation rite, affirmation of superiority over other species, are all in the graffiti of the Altamira caves! The thirst for knowledge induced man to move away from his cavern refuge, becoming an explorer of the world. He searches for other shelters for the night and bad weather, rather than a possible return to his cave. The trees house him. First above and then even under, becoming more brave, strengthened by the security of the power of fire. Here were invented the first forms of huts, originated by bending the branches to the ground, illustrated by Abbot Lougier and treatise writers. In the Renaissance, the symbolic hemispherical shape, which previously was raised for some time in the form of a dome, was already mature to find an even more daring and symbolic constructive form, as advocated in the phrase of Filippo Brunelleschi that, regard to the dome of Santa Maria del Fiore in Firenze, states: "[...] la fece si ampia e gonfia da coprir tutti li popoli toscani" (Manetti, 'Le vite'). The emblematic value assumed by this dome is therefore recognized, which Brunelleschi explained it to his workers with the model of the chalices. The model was intuited by the structure of a vegetable, demonstrating thus the ability to transfer experiences from one world to another. The transitivity of such fantastic inventions was also undertaken generously by the contemporary genius Leonardo. Due to our reasoning, however, what interests us most is basically the prefigurative capacity of the model that holds within itself the principle of doubling, pretending lightness, and hides the grandeur of the structures from the view. As we know, thanks to the invention of the herringbone brick apparatus, with the mutual contrast immediately stabilizing, the dome can be built and so high, without temporary support ribs. In the same period the art of prefiguration recognizes in Leon Battista Alberti the most convinced supporter. Which, practicing the exact form with the field construction drawings, frees the designer from following the construction site. What point have we reached today in prefigurative art?
The control of architecture spatial outcomes, in prefiguration, have reach such sophistications as to bring the user into the most complete simulation of real space and in the condition of being able to act in it; therefore, in space, time and modifying it through the virtualization, which we call Augmented Reality. This, however, highlights that even in moving in real spaces within a distractive way could hardly be perceived as the simulated one, leading us perhaps even beyond our own wishes. A tool that has been tested for decades within programs and technologies available to everyone, is what in some programs is called 'Fly through'. It's true that it does not allow us to feel the warmth of sunlight and similar complexities. Enrolls itself as a perfect duplicate of the buildable but, actually, diminishes it. However, this modest and parsimonious technology feature describes even greater poetry. The 'Fly through', a devise in the field of design aids, allows to configure and display what is the revealer of architectural space: which is light with its variations, a fundamental material, and the gradation of shadows on surfaces. A choice in Architecture for the color of white, which elates, in its monochromatic, life that flows within and aside us, has been defined in that role wisely by Aldo Rossi assigning thus the expression " to be the fixed scene of life", used for the first time in the school of Broni and characterizing his public architecture. The school foyer in Loeches of Alberto Campo Baeza presented in the video, a linear and monochro-

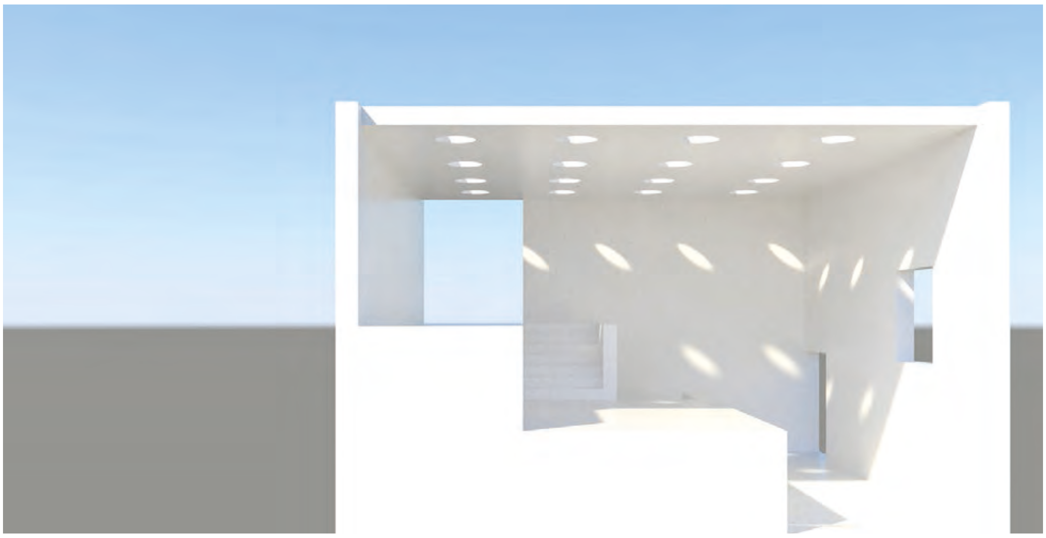

Fig. 1. 3D Animation, elaborated by Antonino Nastasi.

matic film sequence, is an emblematic case which recognizes the values mentioned above and testifies the designer's work experience who wisely displaces the light sources, capturing it within the architectural space continually reconfigured. The cyclical daylight passage will restore to the students, who occupy the space of the school hall, two significant moments of their day: entering and leaving the school. The rain of light coming from the large circles piercing the foyer ceiling, as the sunlight intensity varies, accompanies two moments of the student movements in the atrium space. In going in at school, the light captured at dawn, not very intense, escorts the students towards the interior, creating a mandatory condition for concentrating on study activities. In coming out the luminous intensity of the midday sun announces the outside both with the disappearance of the ceiling due to the sun at the zenith conveying a great intensity of light and with the dislocation of the windows that focus the external ground, horizon and sky, respectively from the upper, intermediate and lower exit floor of the atrium. This declares the resumption of the relations with the materiality of the world, due to cognitive essence elaboration mediated by collective activity and promoted learning.

Measurements

An apparent star orbits the sphere, Earth. Moving along the trajectory of its orbit, relating the planet to the system that both belong to and from which receives light. A dynamics obtained by imposing laws of movement in an adequate program reproducing, in simulation, a portion of the Apparent Solar System complexity.
This allows us to view from the outside and in a faster way, the effects induced by the established relationalities, in the subsequences of the reciprocal recurrence displacements. It is thus possible to 'observe' from a privileged point of view, putting our eye outside the system in which we are immersed, the dynamics of the apparent reality produced on our planet by the mutual dislocations of the spherical bodies mentioned above. It emerges, from the study, how the same exact configuration repetition of the two bodies, in relation to each other, occurs within cyclical cadences, determining variations that affect the temporal illumination quantities of the planet portions. The Earth, receives on its portions the shadow cast, illuminated by the very distant Sun, from which the light emanates. The 'imperfection' of the orbits, not circular, but elliptical, determined by the gravitational forces, generating the perpetuation of the movement, with the functioning of the gravitational forces, as a sort of springs that cyclically load and unload, allows, in a system equipped of substantial energy permanence, to cyclically replicate the reciprocal configurations passing through the 'infinite' others, following one after another. Spheres, representing stars and planets, moving away and getting closer, reveal the formation of particular conditions, in relation to another 'non–regularity',

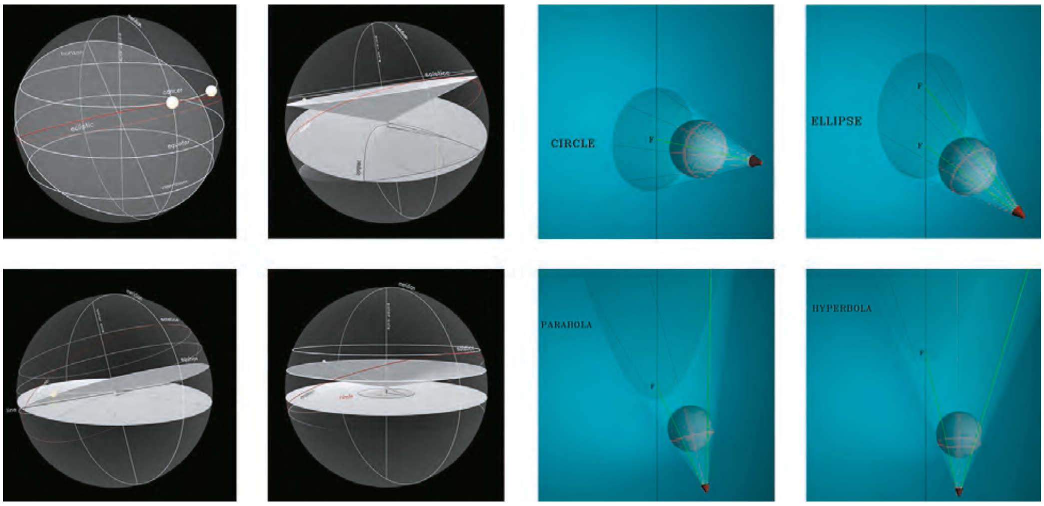

Fig. 2. 3D Animations, elaborated by Antonino Nastasi.

due to the different inclination of the rotation axes of the planets. This demonstrates, in our virtual model of the apparent celestial motions, an unequal distribution of light as well as shadows cast on the various portions of the Earth's surface. Something that we have been aware of for thousands of years and of which, thanks to computer science, we can now simulate with adequate authenticity. This allows to represent the apparent celestial sphere in which we are immersed, through the perceptual measurements of it. Unique measurements identify days in which the amount of light and darkness are equal (equinoxes) and two other days, in which respectively, lightness lasts longer and conversely less (solstices). The empirical model displays how these phenomena are the manifestations of the apparent world, as a result of the 'rotations' of the planets around their axis and of the 'revolutions', consisting in the elliptical orbit path movements. The Earth respect to the Sun and the Moon respect to the Earth. The video animation facilitates the understanding of shadow projections within the theory of conic sections. On one hand an imaginary shadow cone is cut by the plate of a sundial, while on the other the shadow of a sphere is projected on a plane demonstrating the Theorem of Dandelin–Quetelet. An aid of great importance, the scientific knowledge combined with empiricism, determined for example many actions carried out in agriculture, classifying the most propitious periods for sowing, other practices inherent to cultivating, as well as the most appropriate time for harvesting.

Relationships

A big wheel, the orbiting space station and the explorer spacecraft 'dance' in Stanley Kubrick's '2001 A Space Odyssey', to the notes of the Straussian 'Blue Danube'. Choosing this captivating sequence, fragment of the narrated story, it is undertaken a reflection on the relationship between man and artificial intelligence.

The success of the mission is entrusted to the artificial intelligence of HAL 9000, the supercomputer supporting the human crew of the Discovery, as well as the management with the scientist's hibernation on board, during the journey in approaching Jupiter. The exploration was decided after the discovery in a Moon crater of a monolith, clearly extraterrestrial. Enigmatic, the monolith, which sends and receives signals from Jupiter. The true mission essence, started only for exploration by the crew members, is acknowledged by the computer on–board that has ears and eyes throughout the ship, interrelating with humans. Such was implemented in order to make the on–board computer, among other things, also the human guarantor, a sort of their wet nurse. But, every time you rely on something, you also lose a little bit of your individual freedom, ending up at the mercy of it. Now, in coincidence with a damage repaired with an external human intervention, another malfunction relegated the astronaut outside, with his small hull, whose destiny ended up in getting lost in space, once the oxygen had finished for him, losing the commands. Only one astronaut remains in

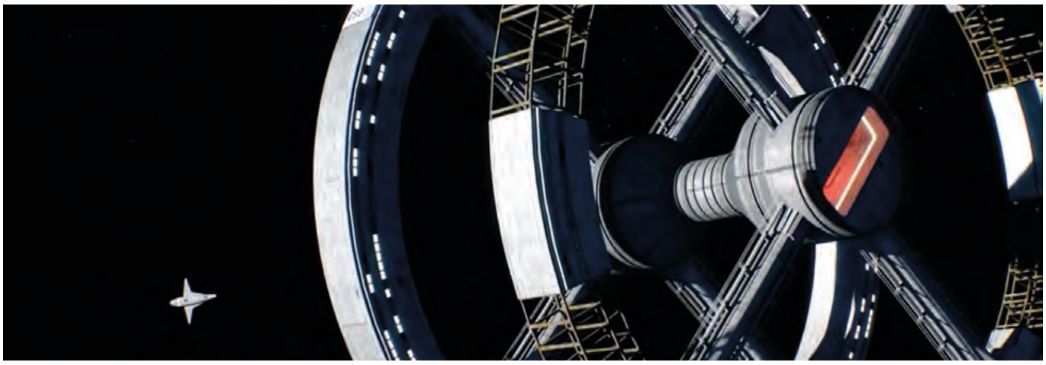

Fig. 3. The frame is taken from the site: fantascienzaitalia.com. Page dedicated to the film 2001: A Space Odyssey by S. Kubrick, in occasion of the 50th anniversary re–release in theaters.

the spaceship with active vital functions, who must program HAL 9000's rejection in order to revitalize the scientists, and reach the site where the exploration should be undertaken by the entire crew. The human man, drawn by this refusal, understands the danger constituted by the 'protective' protocol used by the computer and decides to deactivate it. Therefore, engages a fight of unequal cunning with HAL 9000. If it wasn't for the human factor of the non–linear intelligence endowment, this allows him to have the upper hand in disabling the memory cards. Thus significantly regresses HAL 9000, verified by humming a childish song. The first information was taught to him by his inventor. It was exactly the contradiction between the task of collaborating with humans and the incongruous prohibition, that provided the true crew mission ending in disrupting HAL 9000, and with what could have ensued, if not disabled by man.

Conclusions

(Prefigurations) It is clear, now, how the authors feel that the poetry of architecture can be unacknowledged, consequential of the augmented reality bombardment potentialities, carefully avoiding from becoming sorcerer's apprentices. Certainly good designers will be able to grasp the possibilities offered by today's most performing technologies, and are waiting so that these potentialities decant in order to configure the new changing life scenes.
(Measurements) We should improve these studies and make them more effective to define better our well–being, in relation to animal species, as well as with vegetation and even with the mineral world, taking advantage of the time lap manifestations of the space portions. Therefore, continuously through Space and Time measurements, in which we are immersed.
(Relationships) The topic is clearly highlighted long ago. Respect to today the risk emergence is even more evident, recommending a very supervised use of artificial intelligence. The enormous mass information in which artificial intelligences are continuously self–instructed, reach incongruous actions, treating the data in statistical form that generate a secluded perception with the serious damage in dismantling human critical conscience.

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Authors
Claudio Marchese, Dept. of Engineering, University of Messina, claudio.marchese@unime.it
Antonino Nastasi, Dept. of Engineering, University of Messina, antonino.nastasi@unime.it

 Isbn 9788835125280

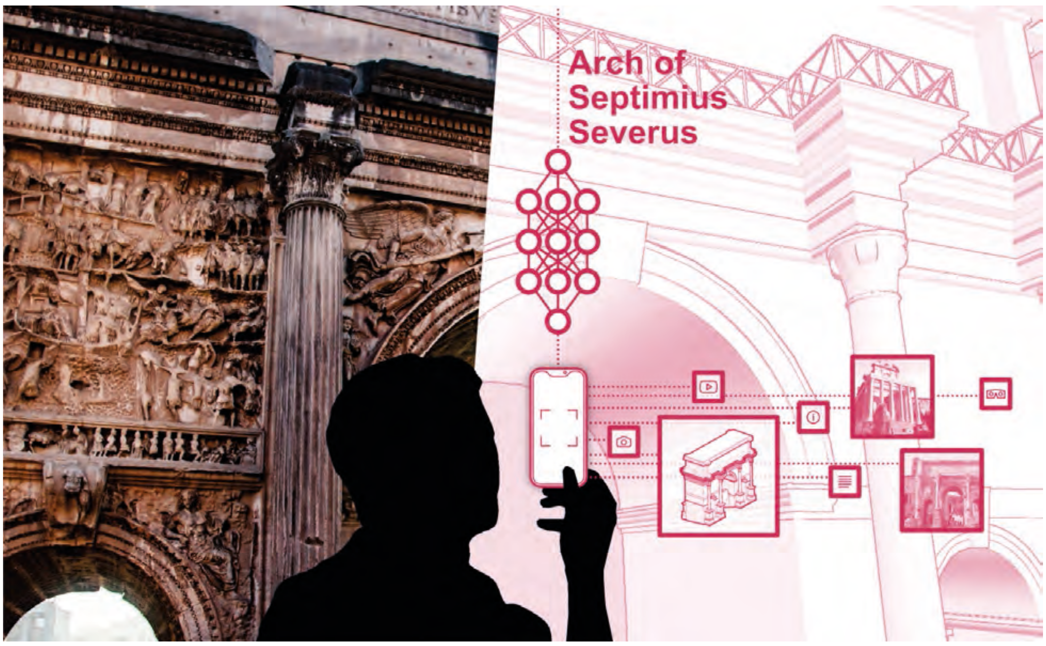
Data, Models and Computer Vision: Three Hands–on Projects

Valerio Palma

Abstract

Advances in information and communication technologies unveil unprecedented opportunities in the documentation and analysis of architectural and urban assets. Nevertheless, the (over–)abundance of data does not always seem sufficient for a thorough understanding. This contribution summarizes three connected research experiences that produced apps and prototypes exploiting geospatial databases, AI for image recognition, and AR based on model tracking, applied to built heritage contexts. The three cases contribute to a reflection on the interpretation of the form of the built environment as a means to produce shared knowledge and operational outcomes.

Keywords
augmented reality, artificial intelligence, digital archives, information modeling.



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Introduction

Much of the narrative about technological advancement associates the collection of extensive and precise data with the quality of our understanding of architectural and urban assets. Augmented reality (AR), artificial intelligence (AI), digital survey, and digital modeling nourish this need for information. On the one hand, these rapidly evolving fields allow for unprecedented and fascinating overlaps and synergies. On the other hand, curbing the hype that surrounds them is often needed. New technologies require attention to their fallibility, to the clarity of the purpose for which we use them, and to the generated models, which mediate our understanding of the documented objects. For example, the problems related to the classification of physical assets affect many tools – and in particular to those of AI, capable of manipulating abstract concepts. As data increase, who chooses the used categories, and how can these be adapted to each application that involves the tools?
This contribution collects some 'fieldwork', that is, experiences in prototyping with technologies to which, increasingly, we entrust the interpretation, classification, automatic replication, and visualization of the built space. The projects described constitute the stages of a branched but coherent research path started at the ICEA department of the Università di Padova and carried on at the Politecnico di Torino, through the activities of the *FULL* laboratory and with the collaboration between the author, Roberta Spallone and Marco Vitali at the Department of Architecture and Design.
The first project concerns the development of a web platform, based on a geospatial database, and designed to guarantee access and interconnection to the multimedia results of architectural and heritage research. The project fostered a reflection on how even the vast digital information topology can benefit from the physical set of sources and their spatial characters. The second project is part of a study on the vaulted atriums of baroque Turin, which produced a catalog of over 70 sites and analyzed the geometric components of the vaults through digital models. The analysis and representation work was integrated with an AR application to visualize the geometric models superimposed against the images of the real vaults. Besides, we designed the system interaction with the web database built during the first cited project. The third project develops a mobile application that allows access to data on monuments by framing a target object with the camera and exploiting machine learning technologies for image recognition. This conjunction between AI and the built space aims at making cultural heritage more accessible thanks to low–cost, non–perishable, and easy–to–use infrastructures.
The research path is an opportunity for reflecting on the processes that, from techniques for the recognition of spatial features – including AI and AR –, produce a schematic understanding and operational uses of the built form.

First Project: a Flexible Digital Archive

The first project, entitled *Tu–Cult*, lasted one year, was carried out at the Università di Padova and was directed by Luigi Stendardo and Andrea Giordano [1]. The project produced a digital infrastructure on which subsequent experiences have relied, and involved several academic and industrial partners and eight researchers in different architecture–related fields – including information modeling, geomatics, history, representation. The project featured the study of two churches in Padova, a small sample made significant by the differences between the two cases and conceived as an incremental contribution to a work on other monuments already started by part of the team [Cecchini et al. 2019].
The team aimed to enhance cultural tourism by means of information and communication technology (ICT). This objective was pursued through three different kinds of outputs: (1) 'data', including documents, raw data, and all the other principal information sources; (2) 'models', that is, 3D models, information modeling, and other data processing products; (3) 'visualization', that is, tools and applications to deliver data and models to the final user through visual interfaces. Therefore, a significant part of the project dealt with the quantity and heterogeneity of the possible interpretations that characterize built heritage – which the

different outputs and professionals involved were able to grasp – and specifically addressed the role of representation as a means for sharing knowledge [Giordano 2017].
The team produced historical and documentary research, detail models and reconstructions of historical phases, BIM models and digital survey models, visualizations in VR and AR. Intending to manage and connect these products, we set up the *[cult]* platform (fig. 1, top left) [2]. It is based on a geospatial database and a set of web services, and makes the project information accessible and connected, even for external applications. The system does not underlie a complex hierarchy – it collects the entries into three simple categories: texts, images, and models – but is based on ease of use and flexibility that have been verified during subsequent projects. The platform was built only with free and open–source software: the web interface was programmed with the Django framework, while the archive is a PostgreSQL database with the PostGIS spatial extension. Metadata are organized based on the Dublin Core standard for resource description [3]. Other technical aspects of the project are described in previous publications [Cecchini et al. 2019].

Second Project: Augmented Reality and the Built Environment

The second project was started at the Department of Architecture and Design of the Politecnico di Torino. The research explores AR applications to the architectural environment and the possibility, already introduced in the context of cultural heritage, of making digital archives accessible from physical objects. The research team – composed of Roberta Spallone, Marco Vitali and the author – had previously employed AR to connect physical archives and databases, within a project on the *Theatrum Sabaudiae*, catalog of the Savoy family residences at the end of the eighteenth century [Palma et al. 2018]. The result was an application anchoring small–scale 3D models to images. This experience evolved into a project to share the results of a study on over 70 Turin baroque atria of the seventeenth and eighteenth century, previously conducted by Spallone and Vitali [2017] [4]. Advances in AR allowed a shift in our experiments towards the architectural scale – even if, in early 2019 (the start of the project), commercial AR technologies mainly supported small–scale applications [5].
We developed an app to view models of the geometric interpretation of the atrium vaults (fig. 1, bottom).
The tests were conducted on a sample of four atria. The objects tracked for AR activation, were three–dimensional objects, of limited extension with respect to the entire environment, such as the base of columns, or capitals. The targets were first registered as sparse point clouds and finally recorded in the app to enable runtime recognition. Since AR tools use many sensors (such as inertial platforms) to track the changing position of the mobile device, the small–sized targets allow visualizing the entire superimposed vault models with fair accuracy – even when the target is no longer framed. Finally, we verified the compatibility of the documentation on the atria with the *[cult]* platform, intending to use it as the database to be navigated from the AR view. In this case, we used the Xcode programming interface, a commercial software allowing free development. Other aspects of the project have been explored in previous publications [Palma, Spallone, Vitali 2019].
This is still an ongoing project since the digital archive based on the atria has yet to be produced. Furthermore, in the current state of technological advances, new solutions should be tested to use AR in the built space.

Third Project: Deep Learning for the Recognition of Architecture

The third project was conducted at the F*U*LL Interdepartmental Center of the Politecnico di Torino [6]. The project aimed to optimize the resources invested in managing BH and the related information, using ICTs. Many solutions already in use at tourist sites (for example audio guides, or self–guided tours with QR codes) still require expensive and perishable infrastructures and ad hoc projects. We have therefore created a solution for connecting the physical environment to the virtual space of information, documents, and digital models, exploiting the capabilities of AI, the developments of which are starting to show the application

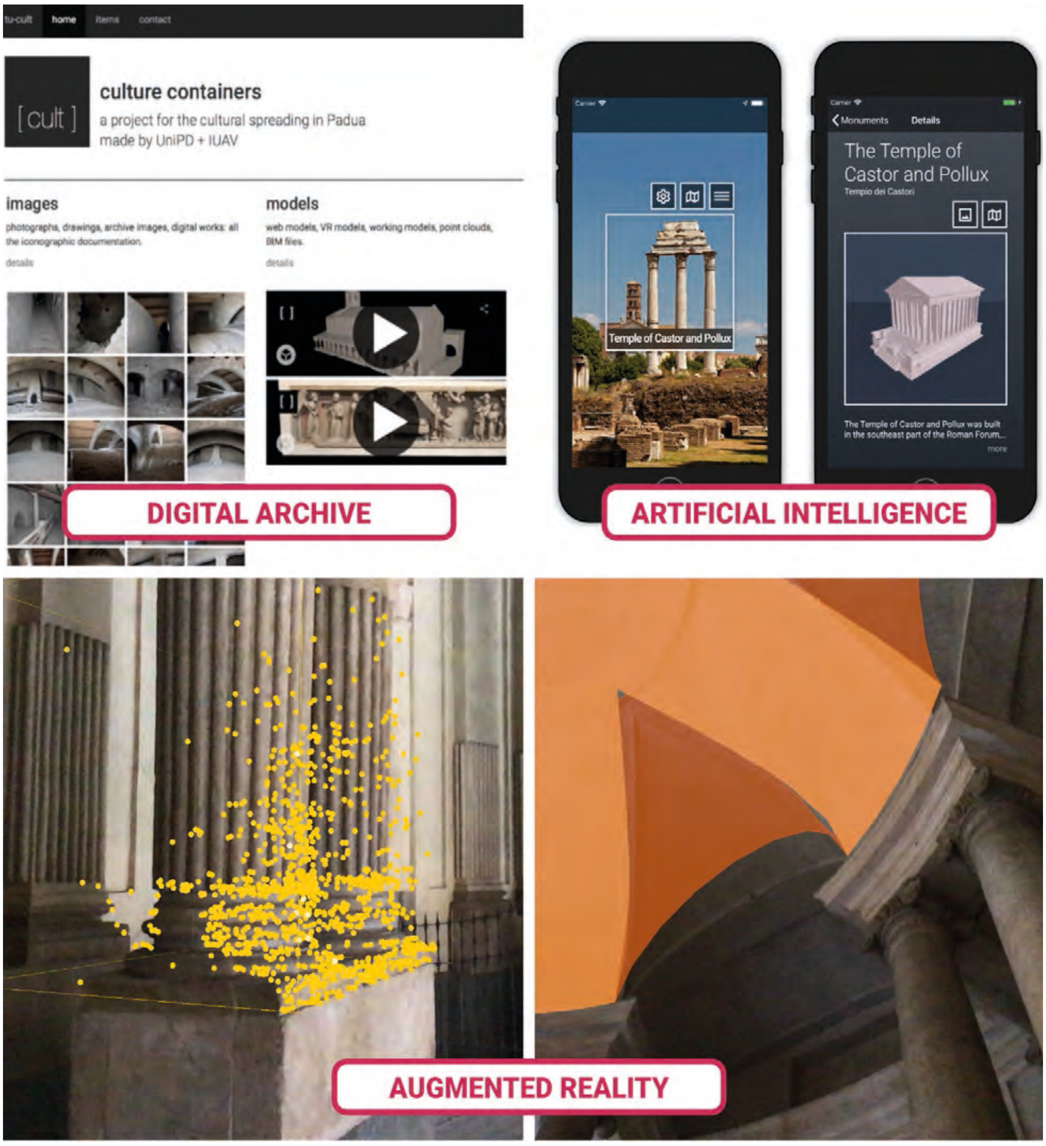

Fig. 1. Top left: the *[cult]* digital archive, public web page. Bottom: model tracking AR; target acquisition as a sparse point cloud (left) and superimposed model in the final app, as tested at Palazzo Carignano, Torino (right). Top right: main views of the monument recognition app.

potential in the built environment [Pezzica et al. 2019]. In particular, we exploited a class of deep learning (DL) algorithms that allows image recognition [Goodfellow, Bengio, Courville 2016]. Therefore, we have created an app that connects to the *[cult]* database and makes it accessible by pointing the camera of the mobile device at a monument (fig. 1, top right). The AI system evaluates the frames recorded by the camera and proposes a forecast of the observed object. Then, the app shows information related to the identified monument, such as descriptive texts, images, interactive 3D models, the position on the map, and other data. For a first experiment, the system was applied in the Central Archaeological Area of Rome, where it allows the recognition of 46 monuments that are very different in shape, size, and state of conservation.

A significant step in building an AI system for image recognition is collecting the dataset for the *training*, that is, the process in which the parameters of the recognition algorithm are optimized for the required task. For this purpose, 50 to 100 photographs were collected for each monument to be recognized, choosing many different viewpoints on the object. The result is an engine that takes up about 13MB of disk space and can distinguish up to hundreds of objects (as an estimated magnitude) from every angle. The aspects that specifically concern the construction of the DL model are described in previous publications [Andrianaivo, D'Autilia, Palma 2019].

Conclusions

Technologies that interact with big–data risk replacing the work of interpreting the built environment and the relationship that binds us to it, be it about culture, fruition, or design. We must prevent a general understanding from being neglected. Theory and models are needed to achieve also detailed data–driven knowledge, to value documentation and collection efforts, and to clarify the purpose of these efforts. The presented series of knowledge access models intends to support the identification of some contexts and scopes that can benefit from experiments with AR and AI technologies. We investigated how digital techniques for spatial character recognition support a theoretical understanding and operational uses of the built form. On the one hand, we must strive to keep the landscape of these possible uses broad. On the other hand, even the schematic understanding of reality that tools produce – the categorizations, the standards – should be kept flexible. Otherwise, automatic recognition and classification become the well–known *black box*, that is, algorithms we accept the results of without questioning how these are produced or whether they can be adapted to changing needs. Finally, experiences suggest that, beyond the schemes we adopt, the tangible aspects of architecture remain a platform for effective knowledge sharing even in the virtuality–pervaded reality.

Notes

[1] The project was funded by the European program POR FSE 2014–2020 – Regione Veneto. A. Giordano was the principal investigator. L. Stendardo supervised the construction of the *[cult]* platform.

[2] ICEA department, UniPD (2017). *[cult] – culture containers*. http://cult.reload.dicea.unipd.it (15 March 2021).

[3] DCMI (2021). *DCMI: Home*. https://dublincore.org (15 March 2021).

[4] In addition to the work of prof. Spallone and prof. Vitali, the research on the vaulted atria benefited from the collaboration of M.C. López González (Universitat Politècnica de València, project "Nuevas tecnologías para el análisis y conservación del patrimonio arquitectónico" funded by the Ministry of Science, Innovation and the University of Spain) and Ph.D. students G. Bertola, F. Natta and F. Ronco.

[5] Currently, some AR software such as Vuforia allow the tracing of very large environments based on CAD models or point clouds. See PTC (2020). *Tools Overview | VuforiaLibrary* https://library.vuforia.com/tools/overview.html (15 March 2021).

[6] The team working on the project at FULL | The Future *Urban Legacy* Lab consisted of M. Robiglio, C. Casetti, F. Frassoldati, L.N. Andrianaivo e V. Palma. The project was carried out in partnership with R. d'Autilia.

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Author
Valerio Palma, Dept. of Architecture and Design, Politecnico di Torino, valerio.palma@polito.it

 Isbn 9788835125280

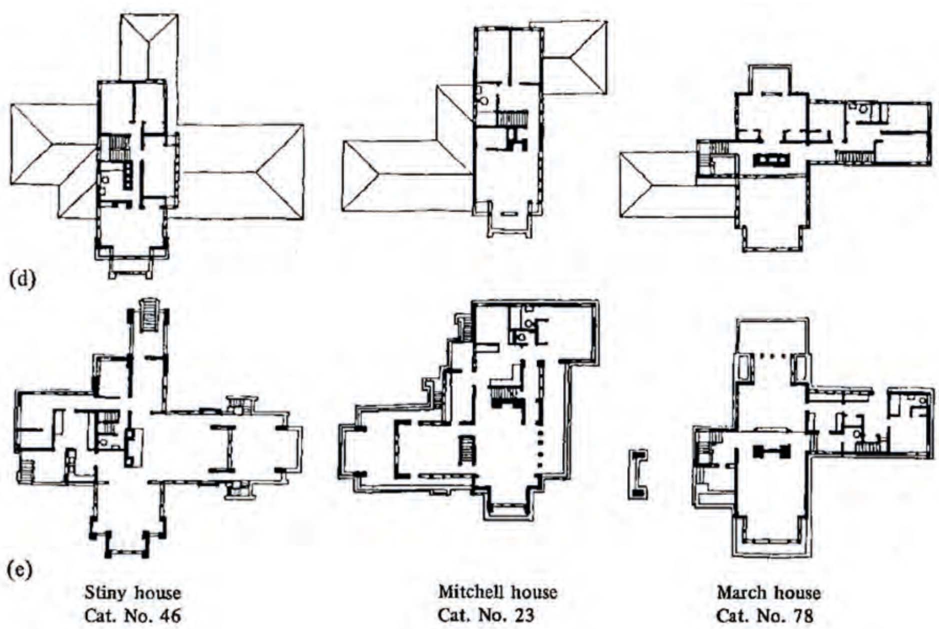
Drawing Automata

Alberto Sdegno

Abstract

The research analyses the evolution of automatic drawing technology, starting with some singular mechanical experiences, such as the puppets by Pierre and Henry–Louis Jaquet–Droz and Henri Maillardet up to developments in graphic technology for digital drawing, such as the ones by Ivan Sutherland, Timothy Johnson and Nicholas Negroponte.
Finally some potentials in the use of intelligent algorithms are described, showing how it is possible to use shape grammar for architecture, as the experiences by Hank Koning and Julie Eizenberg on Frank Lloyd Wright's Prairie houses demostrated.

Keywords
virtual reality, augmented reality, drawing machines, artificial intelligence, CAD systems.



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Introduction

'Drawing Automata' is an ambiguous title. It can mean at the same time 'to draw automata' and 'automata that draw'. But if in the first case the meaning is perfectly in line with the provisions of a certain discipline, the drawing one, in the second case we are in the presence of a phrase that exceeds this work, requiring additional skills, different from those of a good designer who, holding a pencil, draws lines on a sheet of paper.

Here we are interested in deepening in particular the second meaning we have indicated, namely that linked to the themes of Virtual Reality and Augmented Reality, which are among the topics addressed in this symposium. 'Drawing Automata' has something to do with Virtual Reality. In both cases, we can recognize an oxymoron, that is a rhetorical formula that undoubtedly captures attention by 'combining antithetical terms'. On the one hand, in fact, there is the term drawing, which each of us associates with one of the most traditional and creative human activities; on the other hand, the term automata brings to mind the world of the machine – more or less intelligent – which, autonomously from human will, exercises its role in total independence. There is a large variety of automata: from the robots operating in modern factories, to the human–like replicants in the film *Blade runner* by Ridley Scott, which in the future probably will be used also in our houses.

Nicholas Negroponte reminds us that phrases such as Virtual Reality and Artificial Intelligence, to which we could add our *Drawing Automata*, can be considered oxymorons – as we have indicated above – but at the same time also pleonasms, because they amplify the contents they describe, enhancing their semantic value [Negroponte 1995, p. 116]. We could integrate the list with the term Augmented Reality which, even more explicitly, exemplifies the idea of pleonastic enhancement that we described earlier.

We must not overlook the fact that Negroponte himself had underlined the epochal change that took place thanks to technology: from the world of atoms, in fact, starting from the mid–twentieth century to the world of bits, that is to say to the physical recording of information to the digital archives [Negroponte 1995, p. 11] . This current condition sees an exponential multiplication of the bits stored in digital memories, so much so that the neologism *Data–ism* was coined as a meaningful way to describe the period in which we live. The term was used for the first time in a text by David Brooks on *The New York Times* [Brooks 2013], but it has been taken up more extensively into a book by Yuval Noah Harari [Harari 2017, p. 449], in a chapter titled *The religion of data,* in which the author analyzes the epochal change in society, thanks to the invasion of data in our daily life.

Brief History of Automata

We find the term "automata" in one of the first treatises on machines written by Heron of Alexandria, who lived in the first century AD. Published for the first time in 1589 [Herone 1589], the treatise contained no reference to drawing machines, but was full of mechanical tools, some of them have become everyday used. These machines are reminiscent of those developed by Leonardo da Vinci, such as the beautiful gears in the manuscript of the *Codex Atlanticus* [Leonardo da Vinci 2006], drawn with great dexterity and skill already a century before the publication of the translation of Heron's treatise. It should not be forgotten that in Leonardo's library [Vecce 2019] there were some transcriptions of previous codices – such as Taccola's *De ingeneis* [Vecce 2019, p. 91] – from which Leonardo himself certainly took inspiration to draw up his extraordinary graphic drawings as well as some of those that are counted among his inventions. Think for example to the parachute, which the artist proposes in the manuscript mentioned (f. 1058v) in the form of a pyramid and which appears in a manuscript of an anonymous Sienese engineer in the form of a cone.

The first mechanical hand is found in the surgical treatise *Les Oevres d'Ambroise Paré* [Paré 1579], published in 1579. It is called "iron hand" (fig. 1a) by the author who describes it in a precise manner, with the aim of generating a prosthesis for the human limb. Represented in all its details, it recalls that of the "draftsman" (fig. 1b) created by two watchmakers, Pierre and Henry–Louis Jaquet–Droz, a little more than a century later, with the intention of gen-

Fig. 1. from left to wright: a) the "iron man" by Ambroise Paré [Paré 1579]; b) Pierre and Henry–Louis Jaquet–Droz, the draughtsman; c) Henri Maillardet, the draughtsman–writer; d) some drawings by the Maillardet's automaton.

erating curiosity on the part of bystanders [Perregaux 1906, Marchis 1994]. It is a puppet, that draws mechanically and infinitely the same drawing, because its moving mechanisms are regulated by time gears, reminiscent of those of a clock. It is no coincidence that at the same time the physician Julien Offroy de La Mettrie concluded his book entitled *L'Homme Machine* with the sentence: "the body is but a clock" [La Mettrie 1747]. Even today it is possible to see the mechanical doll intent on drawing if we go to the Musèe d'Art et d'Histoire in Neuchâtel, where the restoration of the mannequin made it possible to completely restore the object's operation. In reality, in those recursive drawings there is nothing creative: the mechanism is similar to that used by the first pen plotters of the 1970s which, through a pointed graphic tool, drew lines on the sheets, avoiding the method of inkjet used today. But it is interesting that the drawing is made by an automated instrument and not by a human hand.
Similar to the preceding one is the mechanical puppet realized by Henri Maillardet, who worked in the Jacquet–Droz laboratory [Ceserani 1969, pp. 116-118]. Maillardet's automaton (fig. 1c) was even more sophisticated because it could be programmed to generate different drawings (fig. 1d). So not just one, but several ones, as if it were controlled by an algorithm in which it was possible to modify certain parameters in order to return different results. About these automata, Thomas A. Heppenheimer wrote that "in these inventions we can discern many of the features of today's programmable industrial robots" [Heppenheimer 1985, p. 42], although we have to wait a few years before we see interesting results in the field of intelligent algorithms.

CAD and AI

To find experiences that deal with computer machines that produce graphic drawings we have to get to the 60s of the twentieth century, with the experiences of Ivan Sutherland [Sutherland 1963] and Timothy Johnson [Johnson 1963], authors of the first interactive tools for CAD drawing, in the first case two–dimensional, in the second already three–dimensional, a few months after the first. It is difficult to think that this synthesis could take place without the theoretical support of an authoritative figure such as Steven A. Coons, to whom we owe the first algorithm for the generation of complex surfaces, which take their name from him. Even today, many modeling software describe such forms as Coons Surfaces, an explicit reference to the author who described the algorithm in a well–known essay [Coons 1965]. Only a few years after that experience, Sutherland developed the first virtual reality system – which will be called *The Sword of Damocles*, borrowing the name from the well–known legend told by Cicero. The principle proposed in Sutherland's system – called by him also the *Ultimate Display* [Sutherland 1965] – is contained in every current virtual reality system, even if it presents a system similar to what is now called mixed reality, with the union of real vision with virtual vision. Stereoscopic glasses therefore offer the observer a virtuality that is perfectly superimposed on the actual vision.

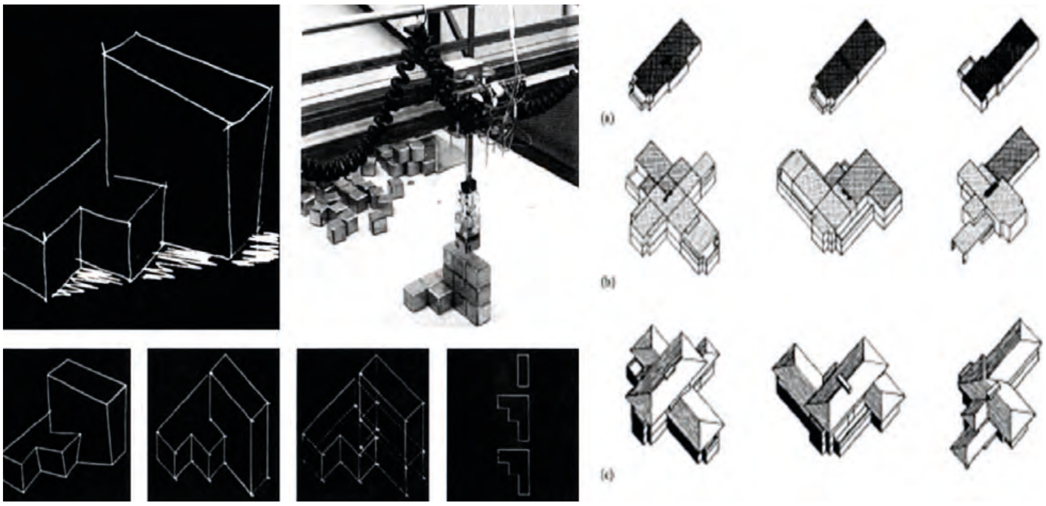

Fig. 2. from left to right: a) N. Negroponte, system that recognizes shapes and constructs 3D model [Negroponte 1975]; b) H. Koning, J. Eizenberg, Shape grammar applied to Prairie Houses by F.L. Wright: Stiny house, Mitchell house, March house [Koning, Eizenberg 1981].

To find the use of artificial intelligence, it is necessary to wait few years, in which shape recognition tools are developed. This is the case of some experiences described by Negroponte in two books, *The Architecture Machine* [Negroponte 1970] and *Soft Architecture Machines* [Negroponte 1975], where graphic recognition algorithms are proposed, which can include graphic signs and return consequent three–dimensional shapes (fig. 2a). But the most interesting experiments will be the ones carried out in the field of shape grammars, and in particular those in which the role of architecture is involved. We thing, for example, at the experiences conducted by Hank Koning and Julie Eizenberg to develop methods of analysis on the works of Frank Lloyd Wright, thanks to which to re–propose architectures in imitation of those of the American architect. So three new Wrightian houses were developed (fig. 2b) to which the two researchers gave the name of three important figures in the filed of computer science, whose studies were decisive in the development of the investigation of architecture using new technologies: George Stiny, William Mitchell and Lionel March, helping to define the process of digital semantic analysis of architecture that is now implemented in many studies. We can remember the ones conducted at Massachussets Institute of Technology by José Pinto Duarte (Pinto Duarte 2001) on the work of Alvaro Siza Vieira, in which the shape grammar of the Malagueira's houses was studied to understand the way in which the architect used the composition rules to design his work, proposing new possible variations of them.

Conclusions

The archives of stereometric forms, investigated in a timely manner with syntactic and semantic analysis tools, can constitute a morphological database from which useful information for the project can be drawn, both by human designers and by intelligent algorithms that can select and propose solutions suitable for different purposes. Precisely this new methodology of intervention gave rise to an acute debate to understand the thin border between human creativity and computational intelligence.

The breakthrough on the table of the designer of the automated drawing is ultimately modifying the architect's work – i.e. we think to the Building Information Modeling process, in which clash detection algorithms can help architect to find problems during the creation phase – so much so as to arouse enthusiasm and anxiety at the same time. A recent essay by Mario Carpo – one of the most authoritative figures in the field of criticism of new technologies for the architect – clearly expressed this status, underlining how developments in algorithmic design can find unthinkable ways out. This reflection is well expressed in one of sentences by him – which closes the cited essay – which summarized the concept with a highly communicative hyperbole: "Architects cannot do without technology, but technology can do without them" [Carpo 2018].

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Author
Alberto Sdegno, Dept. Polytechnic of Engineering and Architecture, University of Udine, alberto.sdegno@uniud.it

 Isbn 9788835125280

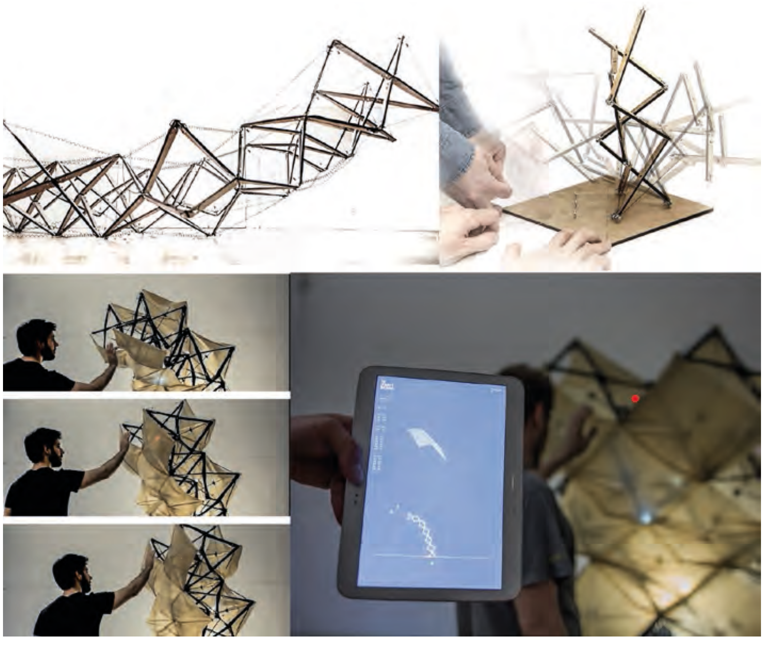
AI+AR: Cultural Heritage, Museum Institutions, Plastic Models and Prototyping. A State of Art

Marco Vitali
Giulia Bertola
Fabrizio Natta
Francesca Ronco

Abstract

The links between representation and artificial intelligence (AI) invade many fields of architectural research, recording continuous and significant advances: they require, on the one hand, a constant update of the state of the art and, on the other hand, careful consideration of the role of Representation in interdisciplinary research in this field.
The present contribution intends to investigate these intertwining in some of the most frequented research fields in recent years: the valorization and communication of Cultural Heritage and cultural tourism, the experiences in the museum field, the research on the role of the prototype within the processes of artificial intelligence applied to architecture.

Keywords
cultural heritage, museum, digital fabrication, artificial intelligence, augmented reality.



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Introduction (MV)

The intertwining of representation – in particular in its manifestations in the field of augmented reality (AR) – with artificial intelligence (AI) spans many fields of architectural research and registers in the contemporary world continuous and significant advances that require, on the one hand, a constant updating of the state of the art and, on the other hand, careful considerations on the role of Representation in interdisciplinary research in this field.
The present contribution intends to investigate these connections in some of the most frequented fields in architectural research in recent years: research on the enhancement and communication of Cultural Heritage and cultural tourism, research on the most recent and innovative experiences in the museum field, research on the role of the prototype within the processes of artificial intelligence applied to architecture.
According to the most recent experiences conducted on the valorization and communication of Cultural Heritage, the most used tools to ensure its success range from the creation of cognitive maps to the development of AI technologies for the automatic digitization of cultural heritage, or the use of Deep Learning for the recognition of monuments and the construction of mobile apps.
In the museum field, artificial intelligence is increasingly used to develop different tools such as robots, chatbots, and websites, which allow analyzing data related to visitors and collections, where the contribution of representation disciplines is nowadays mainly connected to the possible outputs of Object recognition operations and the applications of this technology.
The link between plastic model, AI, and AR is articulated in several aspects based on the 'human–model' interaction and is articulated in some prevalent research strands, such as studies on computational design methods developed for 3D printing and component evaluation, or the work on Responsive Architecture, in which the physical model is the medium through which to experiment and communicate the design of dynamic and adaptive buildings.

AI (and AR) in Cultural Heritage (FN)

According to the most recent experiences with the valorization and communication of Cultural Heritage (CH), they should be the result of a balanced synergy between interaction, experience, and representation.
The current scenario offers research methodologies investigating Cultural Heritage through Artificial Intelligence (AI) tools to increasingly democratize the access of CH, the development of AI technologies for automatic digitization, or the use of Deep Learning (DL) for monument recognition and the development of mobile apps. As an example, the study by Pisoni et al. (2021) proposes the use of AI to support the accessible design of CH. One of the points of greatest research interest is now on eXplainable AI (XAI) techniques, "a suite of machine learning techniques that produces more explainable models while maintaining a high level of learning performance (e.g., prediction accuracy), and enable humans to understand"[Barredo et al. 2020, p. 2]. The tools offered by these developments in technology can enable museums and CH sites to modify their knowledge transmission. By opening up informal learning opportunities to the general public, based on experience and personal interaction with CH, gaps in Natural Language Processing (NLP) and Computer Vision (CV) can be assessed.
Another research approach is that by Traviglia and Del Bue (whose study focuses on the development of AI technologies for the automatic digitization of CH: the different nature of the CH assets does not facilitate the creation of common standards and protocols going in this direction. The main idea of the approach is to incrementally build a 3D reconstruction that is not metric (i.e. where positions are measurable with a metric reference) but rather in the space of projective geometry. In this way, the digitization is made user–independent making total automation of the scanning process possible [Traviglia, Del Bue 2019].
A line of research to be highlighted is that developed by Valerio Palma. He introduces a project aimed at studying the techniques of convolutional neural networks (CNN) in the field of architectural heritage, which workflow has still to be developed. The first steps and results in the development of mobile applications for monument recognition are discussed:

while AI is just beginning to interact with the built environment through mobile devices, heritage technologies have long produced and explored digital models and spatial archives. The interaction between DL algorithms and state–of–art information modeling is addressed as an opportunity both to exploit heritage collections and to optimize new object recognition techniques [Palma 2019, pp. 551-556].
The developments that these research can bring are almost all aimed at enriching the databases, which are still quantitatively limited and refer much towards two–dimensional objects that are "easier" to read in ML algorithms. Another challenge related to AI relates to the use of personal data. The implementations that augmented CH experiences can provide necessarily involve reading and constantly updating regulations and ethical guides for the responsible use of this powerful tool.

The Digital Transformation in Museums: AI and AR as Tools to Engage Visitors (FR)

Within museum institutions, artificial intelligence is increasingly used to develop different tools such as robots, chatbots, and websites, which allow analyzing data related to visitors and collections [Styx, 2020]. The network "Museums + Artificial Intelligence" (n.d), founded in 2019 by Oonagh Murphy and Elena Villaespesa is proof of this growing interest in AI tools applied in this field.
At the same time, VR and AR have become a popular trend worldwide for the dissemination, communication, and enhancement of cultural heritage [Bekele et al. 2018].
The contribution of representation disciplines in the AR field is quite evident: just think of the use of 3D virtual models, holograms, graphics for specific apps, and gaming, up to True AR technology [Sandor 2015]. The group coordinated by Geronikolakis (2020) proposes an interesting application in the field of cultural heritage conservation to improve the experience of visitors, involved in the construction and restoration of archaeological sites.
In the field of AI, the representation disciplines could mainly be involved in the outputs of Object Recognition operations. The applications of this technology involve the user also outside the museum, as in the project 'Recognition', winner in 2016 of the IK award [Styx, 2020] or the application 'Art Selfie'. Several museums base the exploration of their collections on Object Recognition: on color similarities, [Cooper Hewitt Smithsonian Design Museum, n.d; Dallas Art Museum, n.d.], formal, line direction, or space and light [Barnes Foundation, n.d].

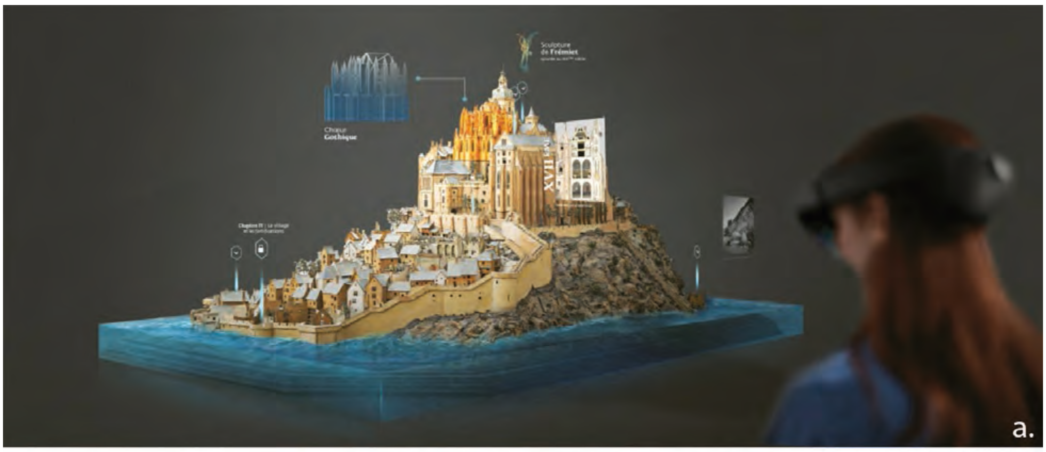

Fig. 1a. Exibition Mont Saint–Michel. Digital Perspectives on the Model (photo by Microsoft, source: https://iciseattle.com/en/mont-saint-michel-in-mohai/); Fig. 1b. The system of ICAR–CNR group experienced in art and tech exhibitions [Caggianese et al., 2020].

In recent years, technologies have made considerable progress in the creation of content tailored to the needs and interests of different types of users, with a democratic and human–centered approach. However, there are still few examples where AI has been used to foster accessibility and inclusion in the field of museums and cultural heritage [Pisoni et al., 2021].
The AI context is certainly characterized by a high level of multidisciplinarity. The mixed–use of AI/AR/VR technologies represents an important field of investigation to meet the needs of an increasingly wide audience, from an inclusive perspective.
The exhibition "Mont Saint–Michel – Digital Perspectives on the Model" (fig. 1a), held in late 2019 at MOHAI (Museum of History and Industry) in Seattle, represents an example of the application of mixed techniques [Ici Seattle, 2019]. Visitors were immersed in the history of Mont–Saint–Michel by framing a real scale historical model of the site with a mixed reality device (Microsoft HoloLens 2).
Another example in this frame is the work conducted by ICAR–CNR [Caggianese et al., 2020] related to the display of Leonardo da Vinci's machines (fig. 1b). This presents the combined use of cutting–edge technologies, such as holograms, with artificial intelligence (AI) to offer the visitor an augmented space involving new forms of interaction (visualization, manipulation, and conversation).

AI in Digital Fabrication Experiences on Architecture (GB)

The link between real model, virtual reality and augmented reality is articulated on two main lines of research. The first one is based on the construction of informative real models, the second one on the interaction 'human–material' through the practices of 'augmented *craftsmanship*' and '*design by making*'. Regarding the first, many studies are now focused on the creation of prototypes aimed at the transmission of knowledge and information of architectural heritage. In the last years, this has happened both through the realization of static models on which to apply immersive technologies, and with more complex dynamic systems in which physical and digital models have come to overlap to the point of almost confusing.
With regard to the application of immersive technologies, reference can be made to the experience carried out for the Basilica of Loreto [Rossi et al. 2017, pp. 239-255]. A project that involved the setting up of a space consisting of a multimedia table with a 3D printed physical model, conceived as a '*wunderkammer*' equipped with a series of technological devices referable to different applications characterized by different levels of interactivity and immersiveness. In recent years, however, rapid advances in technology have begun to challenge even those aspects that go beyond the mere static and physical representation of architecture. An example is the interactive model of InFORM [Follmer et al. 2013, pp. 417-426] a dynamic shape display proposed by the Massachusetts Institute of Technology (MIT), that suggests different ways of physical interaction in real time between users, physical model and digital data. Regarding the 'human–material' interaction, the main fields of investigation concern the application of biological principles on architectural construction and the study of innovative structural morphologies through digital fabrication methods. In particular, the ICD/ITKE Research Pavilions are a series of full–scale prototypes realized through the integration of computational engineering, advanced analytical techniques and digital fabrication aimed at investigating the architectural potential of fiber composites [Doerstelmann et al. 2015]. Regarding the same themes, in London there are also the Protohouse project and the Flow-

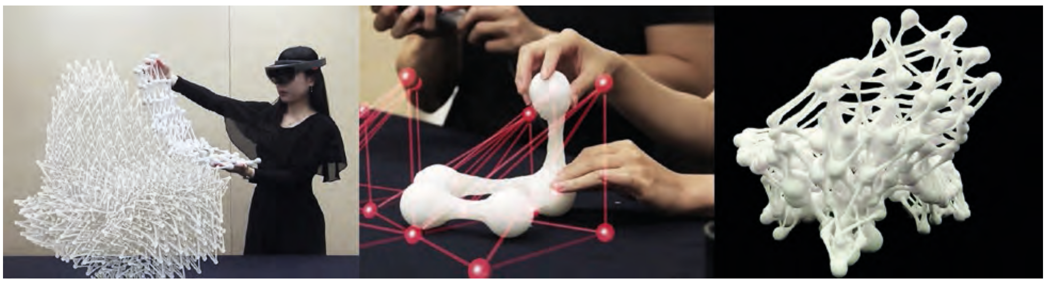

Fig. 2. Project FLOWMORPH [Hahm et al. 2019].

Morph project [Hahm et al. 2019, pp. 553-562] (fig. 2), that proposes an unconventional method of fabrication using *Mixed Reality* to materialize highly complex geometries that could not be realized manually or by robotic fabrication alone.
The practices of *digitally augmented craftsmanship* open to a series of reflections on the theme of interactive digital simulations and their link with traditional craft practices. Mario Carpo, within his book The Second Digital Turn [Carpo, 2017], emphasizes the value of such simulations as they allow today's artisans to learn intuitively, through mistakes, trial and attempts, by making and unmaking as many test samples as possible.

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Authors

Marco Vitali, Dept. of Architecture and Design, Politecnico di Torino, marco.vitali@polito.it
Giulia Bertola, Dept. of Architecture and Design, Politecnico di Torino, giulia.bertola@polito.it
Fabrizio Natta, Dept. of Architecture and Design, Politecnico di Torino, fabrizio.natta@polito.it
Francesca Ronco, Dept.of Architecture and Design, Politecnico di Torino, francesca.ronco@polito.it

 Isbn 9788835125280

AR&AI
virtual reconstruction

Physical and Digital Pop–Ups. An AR Application in the Treatises on Stereotomy

Alessio Bortot

Abstract

This paper focuses on the relationship between stereotomic traces and building construction techniques. Starting from the first essential drawings representing stone cutting methods in full scale – which are still visible in some Gothic cathedrals in France and Spain – it will be analyzed the evolution of stone cutting drawings to the most recent examples in 19th–century treatises. In particular, it will be examined the progress in terms of representation according to different centuries concentrating on the development of theory and practice. It will be therefore given a short overview of the most important Renaissance essayists dealing with changes in representation methods according to the codification of assumptions related to descriptive geometry. In the last part it will be proposed the involvement of augmented reality techniques in order to visualize and study Louis Monduit's treatise on stereotomy through the use of digital pop–ups.

Keywords
stereotomy, Louis Monduit, 3D modeling, descriptive geometry, augmented reality.

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Evolution of The *Trait* in the History of Stereotomy

The research carried out in this paper has led me to study several stereotomic drawings in order to understand the reasons why these 'blueprints' are connected to the concrete practice of construction. The first stereotomic traces are engravings on the floor (less often on the wall) in some European and Middle Eastern Gothic cathedrals. In this regard Calvo–Lopez states "tracings were prepared exactly below the element under construction in order to control the placement of *voussoirs*. Generally speaking, in the Gothic period they were executed on scaffoldings placed under vaults, at springer level, while in the Early Modern period, they were laid directly on the floor" [Calvo–López 2020, p. 127]. The large–scale drawings – which seem to transform the buildings where they are located in a sort of 'stone treatise' – were used to solve specific problems and allow the formal compliance of the piece under construction. In other words, these first stereotomic developments were not intended as a representation of an abstract problem and didn't want to spread construction skills as well. In fact we should remember that in the Middle Ages stonecutters used to belong to guilds that usually concealed every building skill. As a matter of fact, stereotomy was a type of practical knowledge which used to be conveyed orally by the foreman to his stonecutters only in the construction site. In addition, it should be taken into consideration that writing and drawing materials were very expensive at the time. For instance, parchments were much more used in case of public presentations to clients than in standard communication [Erlande–Brandenburg 1993, p. 79]. In this period the most important graphic document is the well–known notebook *Livre de portraiture* by Villard de Honnencourt (... – XIII century). Even if this latter can't be really considered a treatise on stereotomy, anyway gives us a meaningful example of representation in the field of construction site machines, building techniques and use of proportions in the Gothic period. According to Sakarovitch, it is quite interesting to notice that in the carnet by de Honnencour one can find some elements which are represented in double projection despite a lack of awareness in terms of a projective correspondence in the two views [Sakarovitch 1998, p. 41].

We know that stereotomy literature thrived in the Renaissance period basically due to *Le premier tome de l'architecture* (1567) by Philibert de l'Orme (1514-1570) [1]. In this treatise the illustrations show how the medieval secrets – traditionally kept by the guilds – were finally unveiled. The stone cutting techniques spread at the same time as the role of the 'architect' flourished – intended in the modern meaning. From being a 'mechanical art' architecture was gradually turning into a 'liberal art'. What's more, these historical dynamics pointed out the separation between the architect and the foreman (the *maître–maçon*), between the designer and the builder. The authentic expressive medium of the building work is the trait: the technique allowing to trace the layout of the stone structures in order each ashlar to be properly cut. For what concerns this topic, Robin Evans (1944-1993) asserts that the trait is something that is in between two different roles: artisans on one side and architects on the other. Although it isn't part of any of them, it exists as an independent reference such as geometry [Evans 1995, p. 205]. In this period treatises are didactic tools, but also ways to show the skills of the authors, often very critical of the stereotomic solutions developed by their own predecessors or peers. In the treatise by de L'Orme virtuous artifacts arise along with complex illustrations. One of the best examples is the renowned *Trompe d'Anet* – a case mentioned a few centuries later by Viollet–le–Duc (1814-1879) as an "artifice that has nothing to do with the rigorous art of the builder, made to amuse curious spirits with unnecessary problems" [Viollet–le–Duc 1854-1868, book IX, p. 314]. The drawings of this structure (one in pseudo axonometric projection to show the object in a three–dimensional space and some others in pseudo orthogonal projection) aren't able to solve the problem except for a reader who is also an expert in construction site practices. Something similar occurs to other *planches* where geometric operations (similar to 'surface unwrapping') are applied to each ashlar row in order to obtain the corresponding *épures*. In Renaissance treatises it is likely to find a certain need for three–dimensional representations. Thanks to the codification of the perspective laws, in this period these models – which in the Middle Ages were kept secret in the constructor's mind only – acquire education purposes as well.

Several treatises on stereotomy were published in the Enlightenment. This way, cutting solution were codified as well as graphic strategies developed to explain the techniques of division into ashlars. In the huge production of scientific books on this topic it is essential to mention at least the ones by Amedée–François Frézier (1682-1773) [2] and Jean Baptiste de la Rue (1697-1743) [3]. Both are illustrated with high–quality figures using orthogonal projections, axonometric and perspective views of arches, vaults, trompes and staircases. For the first time in the history of treatises on stereotomy some parts dealing with the explanation of general geometrical problems (e.g. conic sections, intersection among shapes, etc.) are included too. This addition is quite important because it reveals a different approach to the relationship between form and structure which can define the superiority of geometry in the field of this construction technique. Other descriptive strategies used by de La Rue suggest the need for a 'stereoscopic' approach which gives the opportunity to go beyond the two–dimensional limits characterizing paper surface such as the use of pop–ups. In fact, his Planche XXXIII describes – both graphically and through pieces of paper which are glued to the page – the mistake made by de La Rue's colleagues in the solution related to the corner segment of a spherical vault. In this sort of stereotomic 'origami' the reader can concretely realize the error by de la Rue's predecessors which is explained developing the faces of the block of stone. More in general, we can affirm that the use of this technique comes from the necessity to control very complex formal configurations such as spherical vaults or trompes.
In scientific literature the tradition connected to the use of pop–ups or movable books dates back to the medieval period [4]. Another example in this field concerns the use of removable paper elements (flaps) or the aforementioned pop–ups in treatises of gnomonics and perspective. Finally, movable books on optics, gnomonics and stereotomy became significant tools when simulating the projective and geometric processes applied to these disciplines, in order to support the representation of elements in space. What's more, three–dimensional paper models used to be designed in order to visualize the cutting flat surfaces of stone blocks in space in order to find the shape of the single faces and define the skin containing the volume.

Louis Monduit's Treatise: a Case Study

I chose the treatise by Louis Monduit as a case study to carry out an experiment on augmented reality. His book was published in a historical period in which stone cutting construction technique was about to be substituted by new methods and materials which were soon the turning point in terms of development in the field of architecture in the 20th century. Stereotomic techniques were therefore strengthened and optimized due to experimentations and publications on the same subject over the centuries. The treatise by Monduit doesn't show any innovation related to cutting solutions, since the case studies included belong to a tradition which dates back to the Renaissance period. Beyond, some features are particularly useful in this research such as the clear projective coherence of the drawings and the general structure that serve specific didactic purposes. This volume opens with a glossary of technical terms in the field of stereotomy and projective geometry. Monduit supplies some definitions referring to the measurement systems and concepts related to planar geometry. Then he draws his attention to the examination of the main proportional ratio, the study of solids, polyhedra (with their development) and a short (but precise) explanation of concepts related to descriptive and projective geometry. A special consideration is dedicated to the method of orthogonal projections which is explained first in three–dimensional space and then on plane. This first section is followed by the study of intersection among solids (cylinders, cones and spheres) – represented in cavalier drawing. This specific part is clearly influenced by the well–established method which was codified by Gaspar Monge (1746-1818) – professor at the École normal supérieure of Paris since 1794. At the end Monduit explains the tracing of the épures and the technical design of the project. Both are useful to develop every ashlar properly.

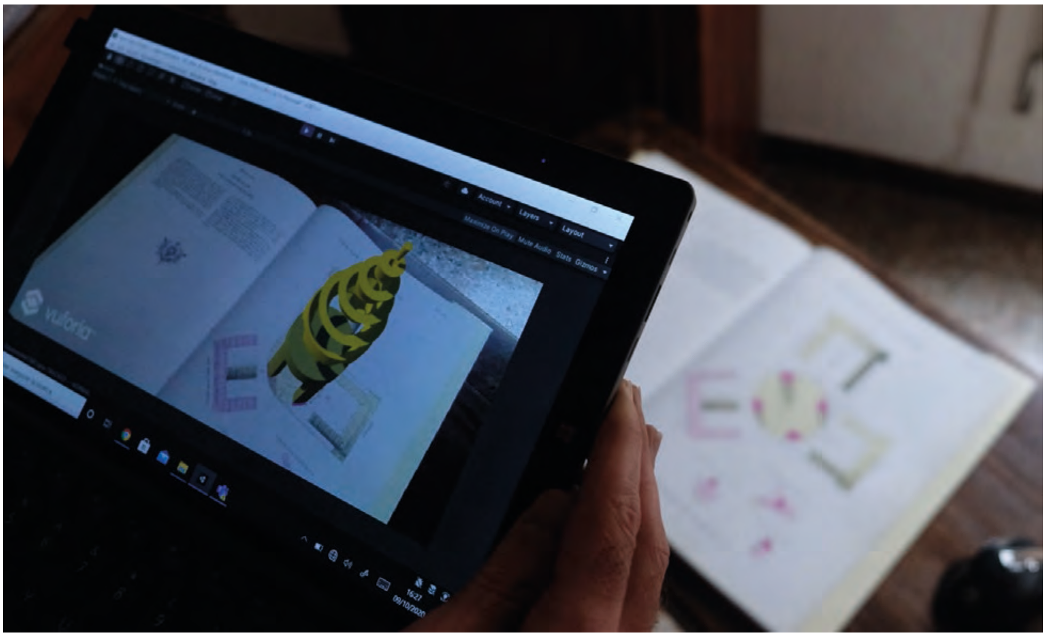

Fig. 1. Exploded view of the 3d model obtained from the digital reconstruction of Planche 46 of Monduit's treatise.

I decided to use digital tools for AR in order to reinterpret the need for three–dimensionality expressed by the historical treatises on stereotomy. The first phase of the work has involved the construction and research on the digital model of the case studies proposed by Louis Monduit. The 3D models were furthermore imported to a Unity software equipped with Vofuria Engine plug–in. As soon as every table in the treatise was set as a target recognizable by the mobile device to display the corresponding model, I defined ambient lights and materials to ensure a successful visualization. The following step involved the organization of contents in the form of an app for tablets and smartphones designed to study the treatise through its digitalization and the definition of models with different semantic values. The different information can be found on the screen overlapped to the real book framed by the device. A first menu entitled 'geometry and shape' allows us to see the digital model divided into blocks, the essential geometric entities representing the cutting planes of the ashlars and the opportunity to observe the model through an exploded view drawing (fig. 1).
For what concerns this device it will be possible to read the Monduit's text through the use of a parallel window in the interface which explains every geometrical phase in the defi-

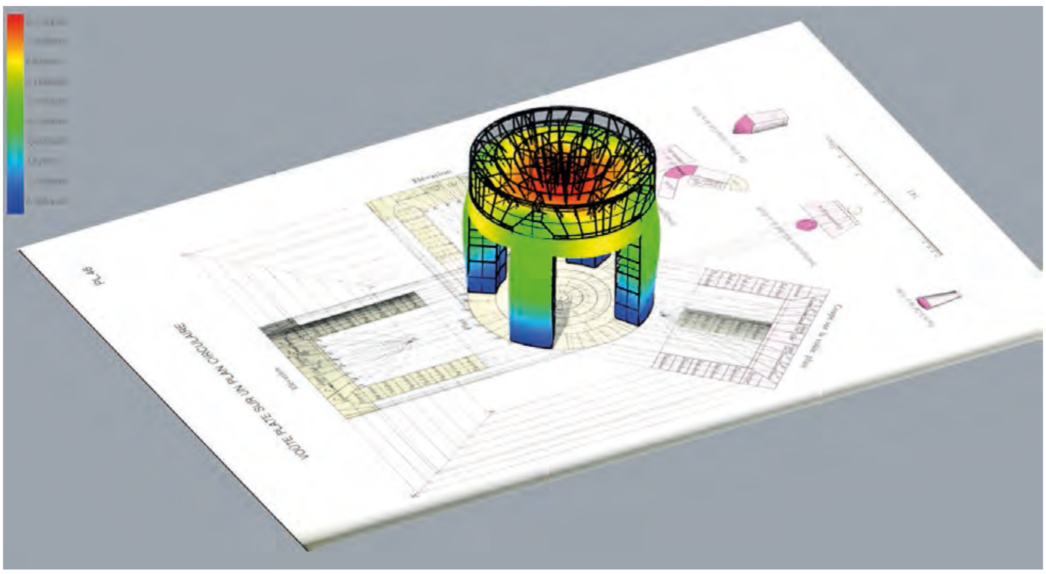

Fig. 2. False color Fem analysis of the 3D model obtained Planche 46 of Monduit's treatise.

nition of various traits. Placing the mobile device in front of the book it will be possible to refer to a database of georeferencing associated with every single case study. This database will gather the existing architectures which were carried out and theoretically described by Monduit in order to obtain an extensible catalogue of stereotomic structures with a description of their own historical and artistic features. Anyway, starting from the important relationship between form and structure in the analysis of stereotomic buildings, I decided to add the opportunity to see a structural model in this app showing the strain of the elements through the use of a false color Fem analysis (fig. 2).

Conclusion

This experiment has shown that the augmented reality can be considered an important tool in the enhancement, analysis and dissemination of cultural heritage through the creation of digital pop–ups. Stereotomy can be considered an excellent field to experiment these kinds of technologies and highlight the closer relationship between geometry and structure while interpreting ancient and complex treatises. In addition, we can state that the use of these technologies must be combined with an in–depth critical development of contents as well. Otherwise the risk is to appear as simple tools of entertainment, instead of sources of knowledge.

Notes

[1] De l'Orme Philibert (1567). *Le premier tome de l'architecture*. Paris: Federic Morel.

[2] Frézier Amedée–François (1737-1739). *La théorie et la pratique de la coupe des pierres et des bois pour la construction des voûtes et autres parties des bâtiments civils & militaires, ou Traité de stéréotomie, à l'usage de l'architecture*. Paris: Guerin.

[3] De la Rue Jean Baptiste (1728). *Traité de la coupe des pierres, où par une méthode facile et abrégée, l'on peut aisément se perfectionner en cette science*. Paris: Charles–Antoines Jombert.

[4] To analyzed this topic, please, see for e.g.: Candito Cristina (2018). Drawings and Models in English Perspective Treatises of the XVII and XVIII Centuries. In Cocchiarella Luigi (ed.). *ICGG 2018–Proceedings of the 18th International Conference on Geometry and Graphics*. Milan: Springer, pp. 1882-1894.

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Author
Alessio Bortot, Dept. of Architecture and Arts, Iuav University of Venice, alessio.bortot@iuav.it

 Isbn 9788835125280

The Value of a Dynamic Memory: from Heritage Conservation in Turin

Maurizio Marco Bocconcino
Mariapaola Vozzola

Abstract

The proposed contribution is the start of a research project on the conservation and care of the memory of urban contexts that are changing and that, while changing, it is desirable to preserve traces of past evolutions. These are particular areas of study, characterised by significant values that need to be known and passed on. Since the beginning of this year, the research group has been dealing with significant experimental cases. On this occasion, some quick elaborations and prefigurations of documentary integration with the existing heritage will be presented for the case of the Borgo Crocetta nursery school building in Turin.

Keywords
cultural and environmental heritage, expeditious urban survey, memory conservation, graphic codes.

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The Study of the Cultural Environmental Heritage of Turin (1984)

The analysis of urban form and the architectural–environmental identity of the built city are themes addressed in various research experiences conducted in the Turin area by many well–known scholars. The experience of the census of the cultural and environmental heritage of the City of Turin has given substance to general urban planning instruments consolidated for Turin in subsequent years and it is now being updated.
In this contribution, we will look at an important aspect of this census, at how digital resources and archives keep alive its cognitive function, at some possibilities of integration that collaborate with the methodological application of the research begun in the 1980s, and finally, we will share some considerations that should support the continuation of our future work.
At the beginning of the 1980s, on the occasion of the revision of its general regulatory plan, the City of Turin promoted research and studies concerning the complexity of its articulated urban system and the scientific approaches necessary to govern its transformation processes. These researches have been carried out by organisations of scientific importance and, in particular, the Politecnico di Torino, under an agreement with the City, has identified, recognised, and classified the architectural and environmental cultural heritage of the entire municipal territory.
The foundation of the identification and classification work was the regional town planning law (L.R. 56/77) and the preparatory studies for the town plan entrusted to Gregotti and Cagnardi (1995). A very broad research team, coordinated by Professor Vera Comoli, which mainly involved two Departments, one from the Architecture area, the House and City Department, and one from the Engineering area, the Department of Building and Territorial Systems; for the engineering area, the area from which we come, there were Pina Novello, Riccardo Nelva and Paolo Scarzella.
As Vera Comoli wrote in introducing the study: "The research uncovers a very articulated and diffuse consistency of the environmental cultural heritage, much more extensive and analytical than the traditional binding recognition, much more differentiated according to cultural specificities, values, and implicit values" (AA.VV. 1984, p. 28).
The methodological approach also involved the identification of a graphic language and representation codes based on municipal technical cartography. The work on Cultural and Environmental Heritage represents a very in–depth field of investigation, especially in the reading of its relationship with the city.
One aspect that has emerged is the importance of investigating ways of preserving memory before intervention in areas of special interest transforms their functional and formal aspects while preserving the identity and recognised elements. In the current state of the art, it is of substantial interest to understand how to implement and update the information collected in the study, published in 1984, to make the permanence of those considerations, updated, accessible in a dynamic way within the information systems dynamically accessible within the existing information systems.
Within the study merged in the publication, a different degree of compatibility with urban transformations was identified to define and order three categories of values linked to protection constraints graded according to the hierarchy of the specific urban quality: assets of historic–artistic value, assets of environmental and/or documentary value, signs of cultural and/or documentary significance or interest. Assuming the criterion of active protection and environmental safeguarding and restoration for all categories of assets, for the for first two the type of eligible interventions is strictly limited.
On the other hand, intervention is possible in areas of cultural and/or documentary interest (*segnalazioni*). In fact, after exhaustive documentation and critical analysis, in–depth transformations can be prefigured, but "sectorial, casual, in any case disqualifying interventions cannot be accepted". We are focusing our interest on this type of property as part of an ongoing experiment.
We think that the mediation of traditional representation tools is experiencing a renewed development and breath through today's ways of support and treatment offered by the

methodologies and technologies produced by information science; these allow many data to be organised using in–depth analysis and digital representations with different and articulated levels of detail.
The sphere of the '*segnalazioni*' assets, for the type of interventions that it allows, makes it possible to exploit methodologies and technologies that make the paths of preservation of memory more agile and keep their presence dynamic; the mediation of the traditional tools of representation lives a renewed development and breath through updated methods for the support and treatment of data; methods that, through the technologies produced by the science of information, allow to organize many elements of knowledge with insights and digital representations with a different and articulated level of detail, integrated into the computer tools that institutions are increasingly sharing (fig. 1).

Methodological Aspects and Initial Scope of Application

The development of integrated digital archives, in which easy access to all types of cultural heritage is made possible, with interactive and hypertextual navigation between the assets themselves, is a significant development. For their implementation, it is necessary to set up a digital inventory complete with databases of real and virtual assets, acquiring digital images with descriptive cards, creating digital images and virtual descriptions, and, where possible, inserting descriptions and three–dimensional representations of the asset, obtained with the most appropriate survey techniques.
Through the selection of a first representative and significant case of the category of assets described above, it is possible to compare the most effective and efficient ways

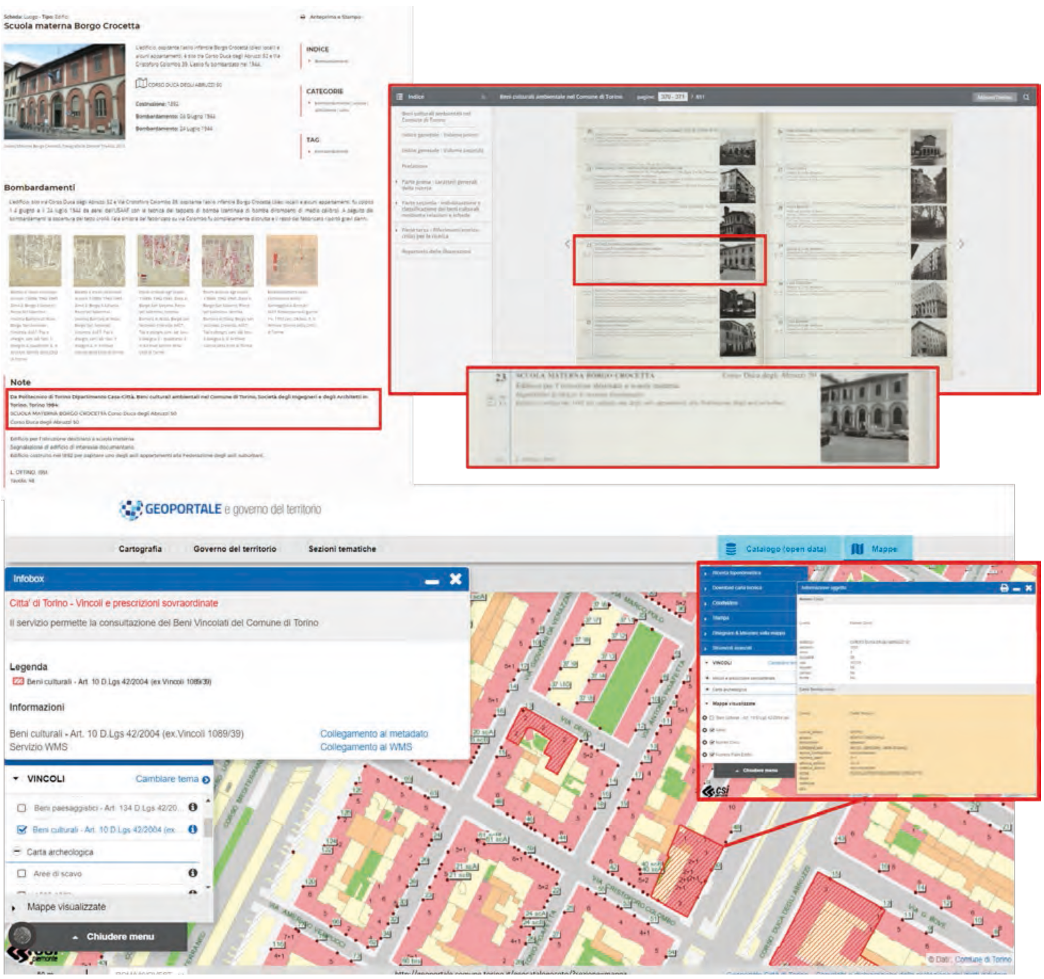

Fig. 1. The case study is based on the analysis of the available documentation. The figure shows a graphic summary of the contents on the MuseoTorino portal and the Geoportal of the City of Turin.

of consultation, which are not limited to orderly cataloging but incorporate processes of an expeditious survey and automatic and 'intelligent' restitution (photo modeling). This is the step that has to be taken to support the management of a multi–relational database, whose information potential is increased by geometric–spatial and textual–numerical dimensions, suitable to be implemented to define, record, disseminating, and processing data and information characterised by individual and contextual specificities.
The '*segnalazioni*' of urban areas of environmental and/or documentary interest indicates buildings and aggregates of the city which constitute significant evidence of a determined historical period and a particular cultural season or possess intrinsic values for a physical and functional improvement aimed at raising the urban quality.
In figure 2 some elaborations were carried out on the Borgo Crocetta school building in Turin, which represents an example of '*segnalazioni*'.
The case study is based on the analysis of the available documentation and investigates more interactive tools that bind knowledge within graphic containers.
The knowledge supports for Turin have for years been stratified in photographic images and maps that are rapidly accessible and consultable, semantic digital archives, Plan instruments and general urban planning instruments.
The existing wealth of information can be supplemented by expeditious and digital surveys, from the photo modeling of the context and of the building at the urban scale, to the instrumental detection of architectural details that can be properly interpreted by artificial intelligence tools and then be integrated into digital information models. By definition, augmented reality offers users the possibility to integrate virtual objects in three dimensions into their living environment in real–time. But there are different ways to do this, including marker–based, or markerless solutions based on global positioning systems (GPS). Solutions based on 'markers', or on location or scene recognition, respond to the sensors of mobile devices and allow multi–dimensional information to be placed in a given location. The stratifications of indications have followed different skills over time.
Their sedimentation can be observed today in the information system of the City of Turin. In this case we observe a partial deficiency, missing an element of connection between studies made, collected in part, and those currently present. In this sense, it will be necessary to pose the issue of criticism and self–criticism on the updates of the Cultural and Environmental heritage, starting from the registration of the size of the urban fabric while recognising the architectural and building value. Furthermore, it will be necessary to create consultation tools that are more ductile and easier to consult and update the data: census resulting from a survey linked to the design of areas linked to the Cultural and Environmental Heritage, producing materials according to standard protocols to support the administrations to verify the reuse of shared data and evaluate integrations.

Concluding Remarks and Future Developments

Integration into the multiplicity of levels referred to must be supported by appropriate dissemination tools; the dimension of the mutations inherent in the same part of the territory investigated in the future or documented through materials of different origin or temporal

Fig. 2. Spatial survey for memory. More 'intelligent' tools that combine knowledge within dynamic graphical containers.

derivation is a relevant aspect, just as the heritage of elaborations contained in the research should not be dispersed, or ignored, if we want to encourage an active and dynamic memory for those significant parts of assets and contexts which, although modified or redefined by interventions made necessary over time, could be kept alive and present in virtual scenarios, in order not to forget their primitive value and integrating the different possible forms of reading and interpretation.
The setting up of a recognisable and still valid method, whose application today is confronted with analysis and recording tools that are more agile and above all more accessible to diversified users with a high degree of accessibility, is today measured by the dematerialisation of knowledge. It is necessary to recognise technologies that are easy to use so that they can be applied widely and homogeneously, technologies that multiply, but above all go beyond, in the permanence of criteria and standards relating to the data and metadata to be stored: the ambition to 'put everything together and in relation' as an interpretation of a problem that derives from alternative technological knowledge that supports information intentions. In this sense, several questions will have to be addressed in the continuation of this research work which has just begun: How should information be managed, does it make the tools chase or does it chase them? How to 'seed' urban memory, material identifiers or global positioning systems?
We are confronted with this: the transformation has taken place and that place today cannot tell its memory, its memory is mute or not everyone can understand it or can interpret it. The paradigm of what urban memory can lose and not transmit through the place itself, in the very place where it was produced, and not only through documentary heritage and archived knowledge, by their nature not accessible to a wide public, not consultable by walking those streets. One can only feel the distant sense of the human and urban reality that occupied that space in the past, but not visualise it, explore it at a distance of time. The seeds of memory need to be planted where memory is constantly being renewed, lost and reformed. The material that constitutes cities must therefore be used to narrate their transformation

Acknowledgements

The present research started under the scientific coordination of professor Giuseppa Novello, former researcher in the original BCA Turin working group, to whom we owe the constant confrontation in many of the critical considerations outlined above.

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Authors
Maurizio Marco Bocconcino, Dept.of Structural, Geotechnical and Building Engineering, Politecnico di Torino, maurizio.bocconcino@polito.it
Mariapaola Vozzola, Dept. of Structural, Geotechnical and Building Engineering, Politecnico di Torino, mariapaola.vozzola@polito.it

 Isbn 9788835125280

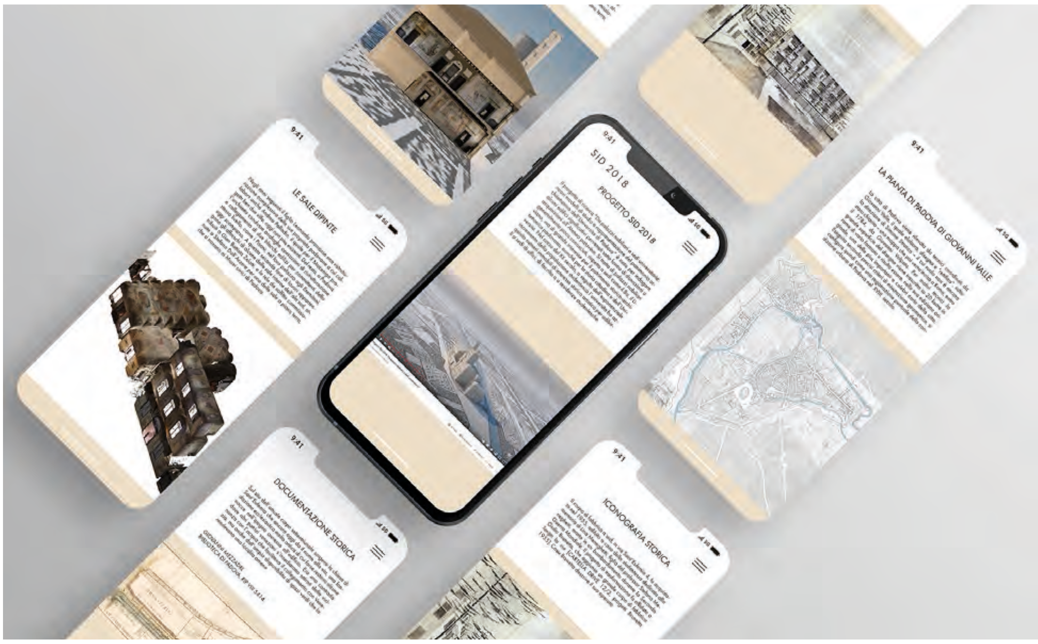
Augmented Reality and the Enhancement of Cultural Heritage: the Case of Palazzo Mocenigo in Padua

Antonio Calandriello

Abstract

Da palazzi nobiliari a sedi universitarie: nuovi modelli di studio e rappresentazione del patrimonio architettonico dell'Università di Padova is the large project which includes the study presented. The aim of the research is to investigate the virtual methods of access and enhancement of the Palazzo Mocenigo Belloni Battagia in Via Sant'Eufemia in Padua. The use of ICT (Information and Communications Technology) is increasingly applied in the cultural heritage sector, especially in the context of museums, in order to increase their inclusiveness and raise the level of use. By exploiting these technologies and applying them to the case at issue, we will try to give visitors the opportunity to virtually see a building closed to the public. Inside Palazzo Mocenigo preserves precious frescoed halls, dating back to the Renaissance period in which the building was one of the major cultural centers of Padua.

Keywords
virtual reality, augmented reality, cultural heritage, virtualization, enhancement.



doi.org/10.3280/oa-686.12

The research project *Da palazzi nobiliari a sedi universitarie: nuovi modelli di studio e rappresentazione del patrimonio architettonico dell'Università di Padova* [1] was created to investigate some significant buildings received in the form of donations or acquisitions to the University of Padua. These are generally little–known noble palaces, compared to sites such as Palazzo Bo, Palazzo Liviano, but of great interest for the Paduan historical–architectural heritage, as well as for the history of the city and University. During the twentieth century, following the exponential increase in the student population, the university acquired real estate numbers of historical and artistic interest to use them as offices, faculties or student residences. Four buildings of particular importance have been identified in the project: Palazzo Contarini in Via San Massimo, Palazzo Selvatico Luzzato Dina in Via del Vescovado, Palazzo Sala in Via San Francesco and Palazzo Mocenigo Belloni Battagia in Via Sant'Eufemia.

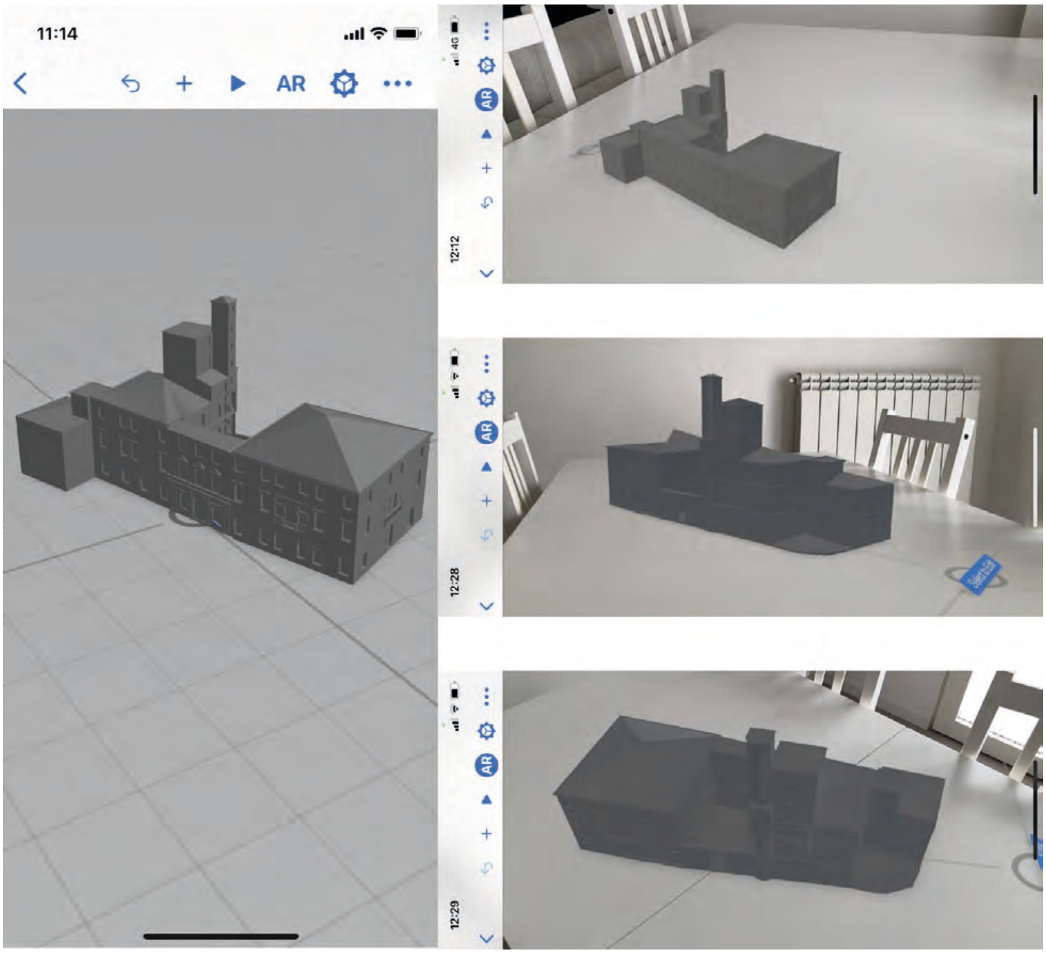


Fig. 1. AR simulation with Reality Composer. (digital model by Antonio Calandriello).

As it appears today, Palazzo Mocenigo is the result of the unification of two distinct structures, built at least in the fifteenth century but profoundly modified, and then connected between the sixteenth and seventeenth centuries. On the site of the current northern body stood the church of Sant'Eufemia which still today gives its name to the street, a very old ecclesiastical foundation. Some traces may remain in the hypogeum attached to the building. It was a city quarter where other Venetian patricians settled, attracted by the proximity to the water that facilitated the connection with Venice, but also by the wide availability of green spaces that made it a pleasant location.
The history of Mocenigo consists of several successive acquisitions, expansions and a restructuring, promoted by Leonardo Mocenigo son of Antonio, which took place in the second half of the sixteenth century. The frescoes in some of the internal rooms of the souther wing – attributed to Gian Battista Zelotti (1526-1578) –, and the ceiling paintings

commissioned to Stefano Dall'Arzere (1515-1575) for one of the rooms on the ground floor – that are now in the Civic Museums of Padua –, belong to this second phase of the work. From this moment Palazzo Mocenigo became a reference cultural center for the city. The building, now owned by the Belloni family, underwent further works in the first half of the seventeenth century, and other rooms were frescoed by Daniel Van Der Dyck (1610-1670). The building as it reaches us today is the result of further changes by successive families and in 1955 it was finally used as a residence for students in memory of Lina Meneghetti. The project was entrusted to Giulio Brunetta (1906-1978) who, in addition to the internal adaptation changes of Palazzo Mocenigo itself, adds a further body of the building. In 1960, the University of Padua also bought Palazzo Mocenigo building, which together with the Brunetta building, has been closed to the public since 2012 following the earthquake in Emilia Romagna.

Fig. 2. Hypothesis of VR simulation with smartphone and Google Daydream View. The VR image shows one hall of Palazzo Mocenigo.

In the case in question, taking advantage of current digital technologies, also borrowed from other sectors that differ from that of cultural heritage, an attempt is made to offer a solution to the impossibility of visiting the property and at the same time, should it reopen the doors to public, offer an increased level of use. Within this process of enhancement it is necessary to underline how the use of ICT (Information and Communications Technology) not only allows a higher degree of use – enhancing the tangible and intangible – and improving social inclusion, but is also able to play an important role also in the conservation of the asset. If we consider the process behind an enhancement project, we will note that this involves an enormous acquisition of data – often of a multidisciplinary nature – which returns a photograph of the current state, both from the point of view of the conservation of the property and of the–state–of–the–art connected to it. It is in this phase that the digitization of the documents that are acquired and processed in order to be adequately disclosed takes place. The study for the enhancement of Palazzo Mocenigo was designed using different digital applications and wants to be paradigmatic also for the other buildings that are part of the key project. Technologies used and intended to be used include virtual reality (VR), augmented reality (AR), video production and application development.
VR can have different levels of interaction, a passive one in which the user 'moves' and another one extremely interactive that gives him the opportunity to interact with space and virtual objects. In the specific case, as will be seen later, we focus on a less advanced level. Augmented reality is a technology that allows you to view additional information in real

time through an overlap between real and virtual elements (dynamic audiovisual content, 3D animations, films). Through special markers and a device, the real image is enriched with features and information that integrate and complete it.
The video production, on the other hand, allows an informative experience through more traditional channels, but at the same time it was the starting point for some of the immersive experiences listed above.
In order for augmented reality and virtual reality applications to work, it is necessary to create digital content to be subsequently transferred into the various software and applications. The first step was to create a virtual clone of Palazzo Mocenigo, this happened in two ways: with a digital photogrammetric survey and with 3D modeling. The digital photogrammetric survey mainly concerned the internal environments – the halls richly decorated with frescoes showing forest scenes with a Flemish taste and the rooms with suggestive painted architectural perspectives – were detected through high–resolution photographs, respecting the criteria of overlapping and spatial distribution dictated by 'structures from motion' software [2]. Particular attention was paid to continuously detecting the interior of the building, focusing on the connections between one environment and another. This approach made it possible to return a unique model of the frescoed rooms and the connecting rooms with the certainty that all the rooms were perfectly oriented and scaled with respect to the others. The information previously acquired and contained in the images of the passage rooms, used simultaneously in different chunks of Agisoft Metashape, made it possible to automatically align the different models of the individual rooms (*Workflow> Align Chunks> (Method) Camera Based*). At the end of all the various phases for the production of the mesh model and its texture, this was exported to be then combined with the virtual clones of Palazzo Mocenigo.
The digital models of the entire building were created through the use of historical documentation as regards the one that shows the formal conformation of the building in the mid–16th century, while for the current state it was based on the digital photogrammetric survey and current documentation. The three–dimensional models, which form the common basis of the various declinations of the enhancement project, were subsequently used in different ways.
The structure of the multimedia project of Palazzo Mocenigo foresees as a first output is the creation a totem that will be located in front of the building itself and that represents the 'stargate' for accessing multimedia contents that are recalled and displayed on their devices by scanning of specific QR codes.
A first QR code offers the possibility to view a video that tells the story of the building, its historical evolution and the transformations it has undergone in relation to the urban context. Paying particular attention to showing what it is not possible to see today, revealing the contents of the internal rooms and passively guiding the viewer inside and outside the building, both in its current configuration and in that of the sixteenth century.
A second tag allows you to download an application that contains a series of multimedia contents, including interactive ones. The application provides that the collection of scientific and educational material is arranged by simple accumulation, starting with the most generic information materials and then descending, based on the user's needs, into a series of increasingly specialized information. Through a 'hamburger' menu it is possible to access the different sections that include the historical documents of the land registry, the State Archives of Padua and Venice, the historical information of the building and its transformations over the centuries, the building at the time of residence student, the 360 ° virtual tours of the various frescoed rooms, the historical information connected to them, and finally the building in augmented reality. Some of these experiences, as in the case of 360 ° virtual tours and the building in augmented reality, can be recalled individually by framing other special QR Codes placed on the entrance totem with your device.
The idea is not to bind the user to necessarily download an application, but to equally use part of the multimedia content made available on online platforms such as Momento360 [3] or to use applications already present in their device as in the case of RealityComposer or ARCore, respectively for iOS and Android platforms. The models of Palazzo Mocenigo

that should be shared on an opensource platform such as Sketchfab [4] and subsequently displayed directly in AR on their devices. The models created for augmented reality allow you to view the formal and distributive aspects of the building and the arrangement of the frescoed rooms in the two reference periods: at present and in the configuration in the sixteenth century (fig. 1).
The virtual tours have been designed to allow the user to mainly explore the interior of the building. Each 360 ° render allows you to explore the interior of the rooms in an immersive and interactive way (fig. 2). Thanks to tags placed on the different points of interest, the user can receive information about the paintings or simply move from one environment to another. The information may be of a different nature, from information about the author, the construction, the construction technique to more interpretative ones, such as for the study of architectural perspectives. This last case would represent the maximum expression of the potential of virtual reality applied to the field of Cultural Heritage. The user would find himself immersed in a completely artificial space that arises from the restitution of the architectures painted on the vaults and on the walls of the rooms. There would therefore be not only the possibility of visiting an inaccessible physical space, that of the rooms of Palazzo Mocenigo, but the possibility of finding oneself even in an different dimension, the one depicted in perspective on the walls and vaults of the building itself.

Notes

[1] Born to experiment new ways of studying, narrating and communicating the historical–architectural heritage received by the University of Padua in the form of donations or acquisitions, the research project started by an interdisciplinary team coordinated by Elena Svalduz as scientific director (Dbc), Andrea Caracausi (Disgea), Andrea Giordano (Dicea), Nicola Orio (Dbc), Stefano Zaggia (Dicea), involved some researchers (Antonio Calandriello, Simone Fatuzzo and Umberto Signori). The writer has dealt in particular with the enhancement project that is proposed here.

[2] The software used for image processing was Agisoft Metashape Pro.

[3] https://www.momento360.com

[4] https://sketchfab.com. .

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Author
Antonio Calandriello, Dept. of Civil, Environmental and Architectural Engineering, University of Padua, antonio.calandriello@unipd.it

Isbn 9788835125280

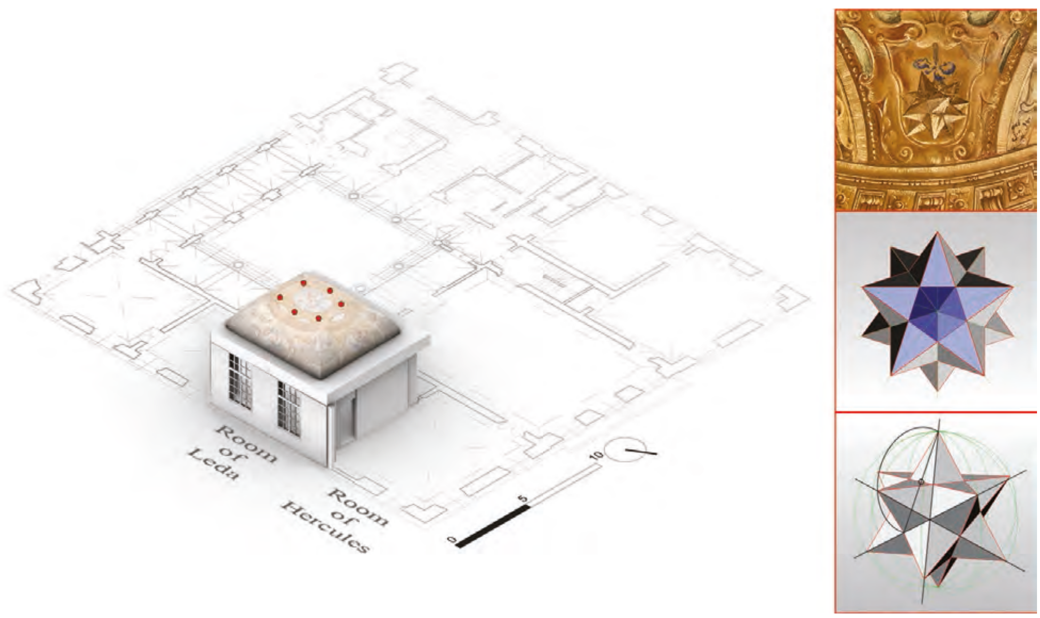
The Appearance of Keplerian Polyhedra in an Illusory Architecture

Cristina Càndito
Andrea Quartara
Alessandro Meloni

Abstract

The illusion of ancient frescoes takes on a new form through the methods offered by digital technologies. This contribution deals with the representation of a geometric solid in the decoration of the Room of Leda in *Palazzo Balbi Senarega* in Genoa: this is the small stellated dodecahedron described by Johannes Kepler in 1619. An in–depth documentary and iconographic research has allowed us to prove that this is the first perspective representation of this solid which took place about thirty–five years after its discovery. The aim is to investigate and illustrate in a communicative, but not simplifying way, the connections between an example of Genoese decoration and the wider seventeenth–century *milieu*, which features artists, scientists, and generous patrons with their unsung brides.

Keywords
stellated polyhedra, Kepler, illusory architecture, perspective, augmented reality.



doi.org/10.3280/oa-686.13

Architecture and Polyhedra in the Room of Leda

This contribution offers an updated representation of the history and meaning of some polyhedra painted in the Room of Leda, in *Palazzo Balbi Senarega*, in Genoa [1]. The Palace, which has been part of the University of Genoa since 1972, was built by Bartolomeo Bianco around 1616 for the brothers Giacomo and Pantaleo Balbi. In 1645 it passed to Francesco Maria Balbi who wanted to enlarge the building and, starting from 1655, hired the best painters and quadraturists for the decoration of the second noble floor.
The painter Valerio Castello and the quadraturist Andrea Sighizzi created the frescoes in the Room of Leda which probably belonged to Barbara Ayrolo, wife of Francesco Maria Balbi who occupied the adjacent Room of Hercules.
To identify characteristics and appropriate modes of representation, we carried out the following analysis [2]:

1. Photogrammetric surveys and nodal photography.
2. Geometric analysis of the represented perspective.
3. Application of perspective restitution procedures.
4. Material and documentary investigations on the polyhedra.
5. Modeling of illusory architecture.
6. Applications of Augmented Reality techniques.

In the Room of Leda, the painted architecture replaced the actual pavilion vault with a golden oval vault, with a large central eye in which the myth of Leda and Zeus was represented. The intent was to fully integrate various forms of art according to the Baroque style. In the present contribution, we improved our investigations about the relationships between real and illusory space, starting from the perspective restitution procedures. In the absence of geometric–proportional references, they are based on the alignment of the projective lines from a point of view (V) generated by an observer in the centre of the room.
The illusory architecture of the oval vault may have been inspired by illustrious coeval architectures in Rome. The oval shape, perhaps prompted by the rectangular plan of the room, may refer to the vault of *San Carlino alle Quattro Fontane* by Francesco Borromini (1634-1644), whose shape is also echoed in the later *Sant'Andrea al Quirinale* (1658) by Gian Lorenzo Bernini and in other famous planimetric shapes of sixteenth and seventeenth century architectures, as the helical staircases in *Palazzo del Quirinale* by Ottaviano Mascarino (late sixteenth century) and in *Palazzo Barberini* by Borromini (1625-1633).
The profile of the illusory vault, in its complexity, could be also be compared with Guarino Guarini's vaults as the one in *San Lorenzo* (Turin, 1668-1687), with their oval openings and their balustrades, that in Turin is the base of the lantern and in Genoa prelude to the sky.
The representation of architecture is attributed to the quadraturist Andrea Seghizzi as well as probably the geometric elements in the Room of Leda, such as the polyhedron, repeated six times. An in–depth documentary and iconographic research on the polyhedron allowed us to prove that it was the first perspective representation of one of the solids described by Johannes Kepler in 1619: the small stellated dodecahedron, which, together with the great stellated dodecahedron, implements the small array of the five regular solids, extending them to non–convex polyhedra. Recent researches on frescoes have also provided an opportunity to obtain new insights into the relationship between art and science in a complex cultural environment of the mid–seventeenth century [3].

The Reconstruction of Illusory Space

The implemented virtual model is a geometric interpretation of the architectural scene represented in the painting of the intrados of the vaulted ceiling of the Room of Leda. Once built the photo–modelling of the vault, the geometric reconstruction of the main architectural and decorative elements took place.
As the first step, we realized a digital model of the room; in this way all the main real architectural elements (i.e. perimeter walls, doors, windows and the frame that run along the impost) configure the digital space in which the 3D photo–modelled mesh has been inset.

Once the real space is configured, we move on to the construction of the virtual space: namely the one depicted on the vaulted ceiling. The imaginary observer – who is standing in the center of the room – individuates the point of view (V): all the subsequent reconstruction steps relate to this point, in order to achieve a straight geometric reconstruction. The point of view (V) is placed at 1.7 meters (hv) from the floor level, simulating the height of a human observer, because we cannot establish a point of view through the internal perspective references. Therefore, a virtual camera is placed at this height and it is tilted zenithal upwards. In order to include the entire space of the vault in a single shot, we choose a wide–angle focal length (about 17 mm). Here it is the first sensible approximation: as is known, wide–angle focal lengths deform the reality, especially in the edges of the frame. In fact, a focal length close to a 50mm on a full frame camera should be used in order to obtain a photographic image resembling the unaided eye view (the so–called "normal vision"). This focal length represents the *optimum* value, since it impresses on the frame an image similar to the one perceived by the human eye and it is therefore able to reproduce a correct proportion of the subjects, according to all three dimensions simultaneously (height, width and depth). By accepting this optical–photographic simplifications, the following 3D modeling procedures turn in a digital model the main architectural elements painted on the golden oval vault. Namely parapet, coupled Ionic columns, medallions, frame, windowed vault, polyhedra and balustrade above the central oval oculus. By observing a symmetrical arrangement of the depicted scene, two orthogonal symmetry axes (x and y in fig. 1a) are defined overlying the hypothetical observer.

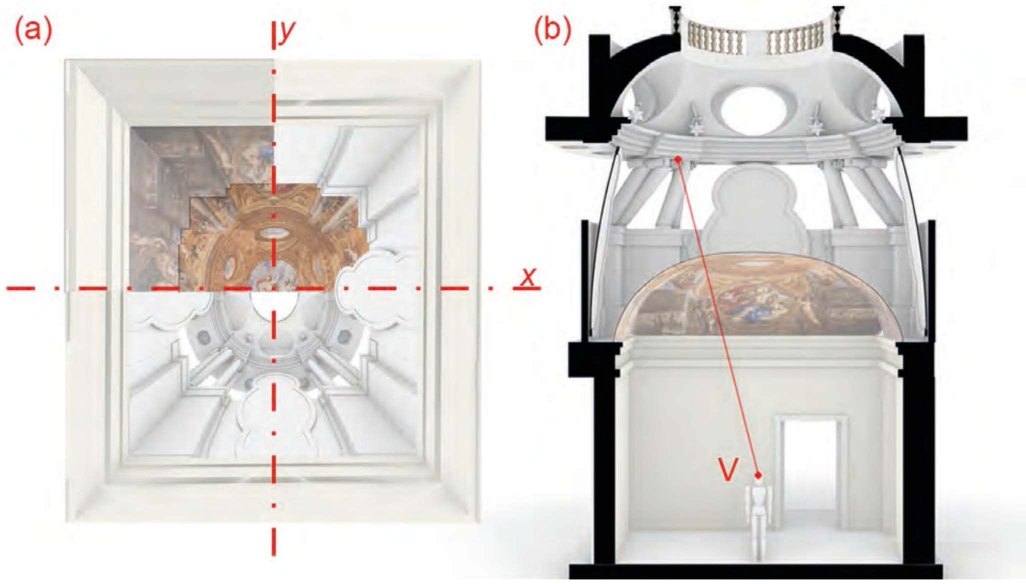


Fig. 1. (a) The Room of Leda frescoes seen from the point of view V. (b) The projection procedures established for the virtual architectural configuration.

The virtual space modeling followed a workflow consisting of two main phases. The first, using perspective projection rays originating in V, defines the heights of elements to be modelled, while the second returns the final positioning of the architectural parts. In this second step the initially modeled solids overlays with the image in rectilinear projection (photoplan) framed by the human eye positioned in V: by adjusting the edges contours and their alignments, the correct approximation of the architecture represented in the painting is achieved. Through the combination of perspective projection and alignment to the photo–modelled mesh texture we carefully modelled every single primary element.
As an example, the sequence applied for the construction of the parapet is exposed.
Phase 1: the projection rays are thrown starting from the observer point of view (fig. 1b); the sizes of moldings (base and coping) and the ones of the parapet vertical body have been defined by means of the relative 2D geometric reconstruction in elevation.
Phase 2: the correct overlaps between the painting of the vault framed from point V and its solid model are adjusted in order to obtain the best possible alignment. To achieve the

whole parapet model, the element is then mirrored according to the x and y axes previously described. As a general rule a vertical arrangement of the elements was assumed. However, we observed an incompatibility in the position of the bases of the columns compared to their capitals which are not vertically aligned. This misalignment was verified through the simulation of an ideal configuration; in the vertical alignment, in fact, the capital would be positioned in the annular extension of the frame of the vault. With the described structural issue, we also recognized a contradiction in the figurative superimposition of the frescoes. These were the reason why we adopted the choice of an oblique arrangement of the columns nevertheless recognizing its incompatibility with an ideal architecture. Furthermore, again to respect the result of the superimposition, an irregular shape of the oculi has been assumed which allows to visualize the cusp of the lunettes.
The modeling of the virtual architecture represented on the vault of the Room of Leda therefore achieves a good approximation by returning a navigable digital environment where the user can observe both the architectural and the decorative elements. The six stellated dodecahedrons hanging with ribbons on the surface of the windowed vault are positioned in the six pendentives symmetrically.

Augmented Reality Applications

The digital model of the architectural space was implemented in its augmented reality version using Unity software (Unity Technologies) together with Vuforia plug–in, thus generating the application to be installed on a mobile device to make visible the reference image and the three–dimensional model associated with it (fig. 2a).
The available augmented reality technology definitely oversteps the two–dimensional representation's limits, providing a set of tools that allow overtaking the simple visualization by offering an immersive experience. AR tools expand the spatial investigation possibilities and they are at once resources for communicating the knowledge of the place which one comes in contact with. Neil Spiller, for example, used augmented reality applications in an unusually suggestive way within the *Walled Garden* for Lebbeus project [Spiller 2014]. In his personal and poetic eulogy to Lebbeus Woods, he overlapped virtuality on the image in order to inspire emotions: in this way he introduced within representation the environmental factors (e.g. weather phenomena and phantasmagorical presences) affecting the spatial reading and that permit to investigate in more detail its representation. Augmented or mixed reality technologies can be used for dissemination purposes to take advantage of spatial

Fig. 2. Elevated and stellated dodecahedra, the red line highlights the continuity or discontinuity of the sides. (a) View of the small Keplerian stellated dodecahedron in the Room of Leda through Augmented Reality. (b) J. Kepler, 1619. (c) P. Uccello, 1425. (d) L. Pacioli, 1509. (e) D. Barbaro, 1569.

analysis features and streamlining the interaction process between the architectural environment and the viewer, while making it intuitive and direct. The application of this systems allowed us to highlight differences between the unaided eye view of the Room of Leda frescoes and their virtual reconstruction. Moreover, it was possible to focus on the understanding of the small stellated dodecahedron, which turn out to be the first perspective representation of this Keplerian solid, as claimed previously. It may be interesting to show the peculiarity of this prodigious solid by exploiting the highly communicative and immersive AR experience. In fact, the small Keplerian stellated dodecahedron is distinguished from the common elevated dodecahedron thanks to the continuity between the sides of the pentagons of the original dodecahedron, with the edges of the pyramids of the contiguous stars (fig. 2b): a property that can be better understood through virtual model that appears in our devices enhanced by perceptual information. The real–time interaction with the 3D solid emphasizes its peculiar geometric properties. Thanks to this observation, the iconographic meanings of this innovative scientific presence can be illustrated in a simple way in a seventeenth–century fresco of a lady's bedroom, whose beauty is honored thanks to the golden ratio harmonies of the geometric solid [4]. The comparison with its illustrious predecessors is of interest too. So, we can show the orthogonal representation of the solid appeared in a mosaic of the basilica of San Marco, traditionally attributed to Paolo Uccello (around 1425) (fig. 2c). We can also cite the illustration by Leonardo da Vinci, contained in *De divina proporzione* by Luca Pacioli (1509) which represented a generic elevated dodecahedron with reduced projections and the consequent lack of continuity described (fig. 2d), which was also found in the perspective illustration by Daniele Barbaro (*The practice of perspective*, 1569) which described an elevated dodecahedron with much taller pyramids (fig. 2e).
Room of Leda and its features (spatial, geometric, artistic and historical) should be perceived by the widest possible audience. The use of augmented reality allows us to make them also accessible to people with disabilities. The use of an easy–to–handle device is preferable by people with mobility impaired. The possibility of using transcriptions and audio descriptions regarding the main characteristics can help to enhance accessibility for people with hearing and visual disabilities. It is therefore an intervention that implements inclusivity, addressing different age groups and people with cognitive disabilities too. AR technologies experience is seamlessly interwoven with the physical world such that it is perceived as an immersive aspect of the real environment full extent and not competing the frescoes, helping in clarifying some artifices of the past.

Notes

[1] The paper was conceived and elaborated as a team–work: the paragraph *Architecture and polyhedra in the Room of Leda* was written by C. Càndito, *The reconstruction of illusory space* by A. Quartara, and *Augmented Reality Applications* by A. Meloni.

[2] Analysis from 1 to 4 were realized by Cristina Càndito, with the collaboration of Ilenio Celoria for the point 1; operation 5 by Andrea Quartara and 6 by Alessandro. Meloni.

[3] For the identification of the polyhedron and the artistic and scientific influences on Seghizzi's work, cf. Càndito, Celoria [in press].

[4] For meanings related to golden ratio perfection and hypotheses about their implications, cf. Càndito, Celoria [in press].

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Authors

Cristina Càndito, Dept. of Architecture and Design, University of Genoa, cristina.candito@unige.it
Andrea Quartara, Dept. of Architecture and Design, University of Genoa, andreaquartara@gmail.com
Alessandro Meloni, Dept. of Architecture and Design, University of Genoa, alessandro.meloni@edu.unige.it

Isbn 9788835125280

Digital Tools at the Service of Public Administrations

Maria Grazia Cianci
Daniele Calisi
Sara Colaceci
Francesca Paola Mondelli

Abstract

Competitions for ideas for architecture have always been sources of stimulus and research, paving the way for innovative projects that have also guaranteed an economic flow and a naturally consequent social response.
The municipality of Rome, years ago, was the architect of a campaign of this type: the *Cento Piazze* project included, for the first time, a number of competitions and projects that had never been addressed by a national and international administration.
Our intervention aims to reflect on how and to what extent the Public Administration can now benefit from new technologies and digital tools for the analysis and survey of architecture and public space. These innovations, in fact, now make it possible to provide design with a valid help in the preparation of competitions that increasingly concern urban regeneration at an international level.

Keywords
public administration, survey, cento piazze, heritage digitization, planning.

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The *Centopiazze* Program

In 1996, the *Centopiazze* program in Rome launched the national competition *The neighborhood squares*, through which young professionals were invited to deal with the design of 19 open spaces in Rome. *Centopiazze* was a unique urban redevelopment program of its kind in Rome, through which it was intended to deal with the issue of public space extensively throughout the territory, from the center to the periphery. With the council led by the Mayor Francesco Rutelli, and on the proposal of Prof. Arch. Francesco Ghio, a special program coordination office was set up in the Mayor's Cabinet. Over the course of about a decade, around 180 public spaces in the city have been transformed, redeveloped or built from scratch.
The Neighborhood squares competition was the first action through which the *Centopiazze* program was launched. It is very interesting, to date, to look at the competition dossier precisely in order to compare the ways in which, 25 years ago, the areas of intervention were presented with respect to today. The graphic and technical documentation present in the competition dossier reflected the possibilities and means of the time: first of all, a technical plan of the intervention area, with the area within the key–plan of the city of Rome; a brief description of the area with an indication of the functions to be established, location, morphological characteristics of the area, road system, green system, urban context, historical analysis, urban destinations (with reference to the PRG in force in 1996) and the further planned projects in that area; some exemplary axonometric diagrams through which the different lots involved in the competition were compared, drawn with wire; finally, in the most fortunate cases, an aerial photo of the area and some photographs of the site.

Reinventing Cities. Historical–Documentary Research and Surveys

Today, after more than 20 years, the city of Rome confronted again with the theme of urban regeneration and does so through the Reinventing Cities international competition, *A global competition for innovative, resilient and zero–emission urban projects*. 12 cities on 4 continents have so far taken part in the competition.
Among these, Rome participates with 4 different areas that will be subject to redevelopment: Ex Mira Lanza in the Ostiense–Marconi area; Ex–Filanda in the San Giovanni area, close to the Aurelian walls; Ex Mercato di Torre Spaccata, Vertunni, in Torre Spaccata area, on the eastern outskirts of the city; and finally the area of the Roma Tuscolana station.
The municipality of Rome has decided to entrust the preparation of historical and analysis documents and the survey of the three areas currently subject to competition as an external assignment. The Roma Tre architecture department was awarded the assignment with the scientific responsibility of Professor Maria Grazia Cianci, thus starting the historical documentary research. For the realization of the three competition dossiers for Ex Filanda, Ex Mercato di Torre Spaccata and Ex Mira Lanza, the working group then dealt with the historical archival research and the elaboration of the integrated survey model, and also with the writing of the texts and graphic design. The dossiers open with a timeline that traces the main stages and transformations of each building, and a chronology drawn up in a discursive, more in–depth and explanatory form. The first two chapters of each issue concern the urban setting of the project sites, and an analysis of the main historical cartography for understanding the territorial and urban context, described and reasoned through the accompanying text. The maps were chosen and placed side by side, suggesting a critical comparison between the different drawings, as in the case of the study of the area where the Ex–Filanda building stands. The topography of the area, leaning against the Aurelian Walls, is compared in the two maps of Du Perac and Bufalini: the first, perspective, shows the lay of the land beyond the walls, in contrast with the dense urban intramural fabric; the second, more technical and zenith, clarifies the territorial conformation with the vallis celimontana in which we see the *acquae vocatur marianae* flow, the so–called *Marrana di San Giovanni*.
The dossiers contain all the graphic archive documentation that resulted from the historical research: drawings, projects, surveys, contracts, and historical photographs that are significant for the exhaustive description of each building, tracing the history of each of its transformation. Many sources and archives were consulted, including the Capitoline Historical Archives, the Archives of the Conservatory of Heritage of the Municipality of Rome, the Archives of the Istituto Luce, the Central State Archives.

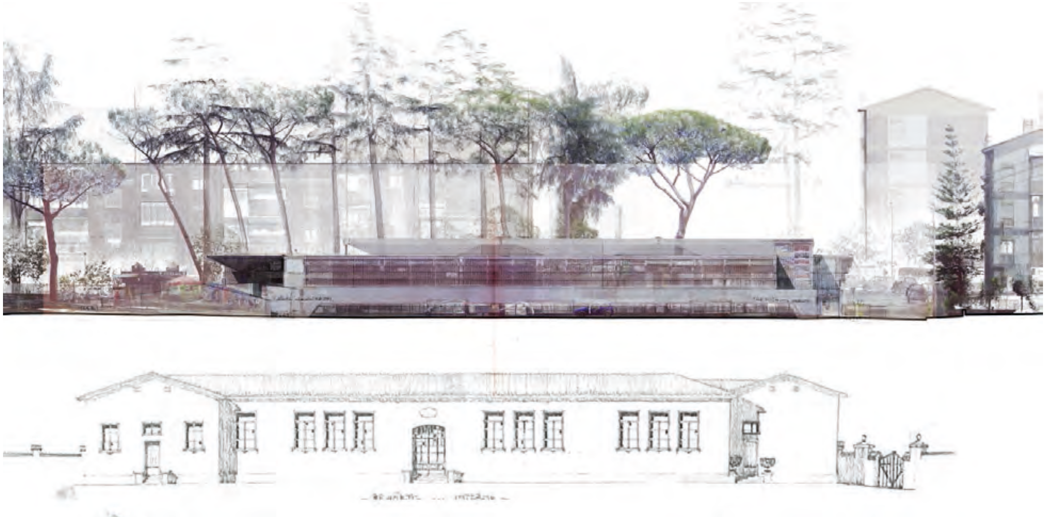

Fig. 1. Ex Mercato di Torre Spaccata, side elevation: overlaying of the original project drawing on the orthophotoplan from point cloud.

Since these are archival documents that are also very dated, each drawing has been the subject of a careful cleaning and graphic post–production which has been aimed at making the original signs as legible and clear as in the case of the projects attached to the tender specifications for the construction of the pavilion of the Ex Filanda in the Castrense valley: original documents from 1920 preserved in the contract fund of the Capitoline Historical Archive. Based on the results produced by archival research, the various types of documents were presented within the files in order to offer critical and reasoned insights, as in the case of historical photos. In the case of the Ex Mercato di Torre Spaccata, for example, the current state of the building was described through historical photographs resulting from archival research, highlighting the transformations that have taken place over time.

The laser scanner survey represented a separate part of the assignment, as the processing of the point cloud of each of the areas was requested. To obtain it, it was necessary to integrate two instruments: laser scanner and drone. The two point clouds obtained were geo–referenced and superimposed.

It was decided to present the original technical drawings of the project by offering a critical reading, comparing them with the contemporary technical data represented by the orthophotoplanes that resulted from the processing of the point cloud obtained by laser scanner and drone. In this comparison made on the façade of the Ex–Mercato on via Settimio de Vico, for example, we observe the homogeneous character of the external walls characterized by the stepped profile that follows the profile of the internally arranged 'mushrooms'. The comparison between the orthophoto and the relief drawing of the 1980s shows the perimeter closure above the market boundary wall.

Even in the case of the former spinning mill, the same method of analysis was applied: the orthophoto of the elevation on the internal courtyard, for example, was compared with the original project drawing, highlighting the changes that had taken place. It is possible to note, in fact, the construction dating back to 1965 of the accessory bodies that lean against the facade, built once the building was managed by the *Servizio Giardini* of Rome, and which still houses the offices. In this sense we intended to give scientific value to the work: not a collection of documents, but an integrated re–reading and re–elaboration through modern instruments and their conscious use (fig. 1).

Another important fact, in the case of the Ex Filanda, concerns the historical reconstruction that was offered through typological analogy. In fact, this building, built in 1920-1921 by the Municipal Administration with funds from the Roman Committee of Civil Organization for the educational, moral and sanitary assistance of minors living in degraded situations (later known as *Ifantiae Salus*), it was not possible to find specific archival photographic documentation. However, since this is one of the three *Infantiae Salus* pavilions built in Rome in the 1920s, it was considered useful to refer to and insert in the file the documentation relating to the other two buildings: that of Trastevere and that of Testaccio.

The Digitization of Archival Documentation and Built Heritage

One of the main problems that public administrations in Italy are facing is the digitization of the entire archival apparatus, not only linked to bureaucratic aspects, but above all land registry and concessions and licenses. Considering that the European directives require the use of BIM in public procurement (from 2025 also for minimum contracts of € 100,000), the administrations are already in strong delay in the digitization of the built heritage which is part of the future programmatic planning of the master plans. The three case studies object of the *Reinventing Cities* campaign have for years (or decades) been strategic sites for the municipality of Rome, the subject of the study of projects for urban redevelopment and regeneration and subject to a succession of events that have greatly entangled the bureaucratic skein made up of restrictions, prohibitions and permits.
In this background, the urgency required by the call for the execution of the three surveys with laser scanner technology to be provided to the participants is no coincidence. This concern has necessarily imposed a rational and programmatic planning of the survey campaign, taking into account the potential of the tools and the due overlap from two reciprocal laser scanning stations. At the same time, the authorizations were requested for drone flights that were necessary for the photographic campaign and the creation of the discrete 3d model in SFM of the roofs (absent in the ground positions).
The point clouds, with a detail of a point every ± 1mm, were mutually aligned in ReCap and subsequently georeferenced, as specifically requested by the PA, thanks to the markers positioned at ground level and for which GPS data has been recorded. The point cloud created for each project site does not, however, exhaust all the drawings needs of a design team. In fact, although it allows the navigability of the site digitally, its interrogation on the formal and dimensional aspects or the perception of the neighboring context, the point cloud must be imported into the CAD environment to provide two–dimensional drawings in orthogonal projections through its management with cutting plans and the redrawing of plans, elevations and sections. This operation is essential to provide the basic iconographic apparatus for the canonical drafting of an architectural project (fig. 2).
Not all PAs or even architectural firms know how to manage point clouds whose management, reading and interpretation requires experience first of all in the science of drawing, of its discretized representation, in different scales, of reality, be it real or virtual. In addition, knowledge, however technical, of the appropriate software is needed to obtain the desired results. The research group engaged in the work of historical research, survey and representation of the competition sites, had to produce plans, elevations and architectural sections, as well as orthophotoplanes useful for understanding the state of decay of the places. Furthermore, the parametric three–dimensional model was created, starting from the point clouds, from two–dimensional CAD and having a constant control with archival documentation, in regard and verification of all design phases.
The work carried out, in record time, was certainly a first positive experience for the Municipality of Rome, a springboard that highlighted many issues of significant importance, first and foremost the need for a digital database of the architectural heritage that allow to accelerate the bureaucratic and planning processes of public procurement.

Conclusions

While it was once the practice to provide two–dimensional CAD, today technology has allowed administrations to add a third dimension and present instrumental surveys performed with laser scanners and photo–modeling carried out with the flight of a drone as basic material. The point cloud thus obtained will be the three–dimensional basis for design studies, inserting two non–negligible factors into the process. First of all, the now inevitable need to survey, survey and catalog the archaeological, historical and contemporary architectural heritage through tools that are not usual for public administrations and consequently the need to make use of professional technicians in the sector.
In our opinion, moreover, the digital processing of the surveys required by the PA as basic documentation of the insolvency procedures, can represent an intermediate phase towards what could become a real virtualization of the inspection and survey by the designers. The

translation of the point cloud and the three–dimensional model into an augmented reality experience could pave the way towards the possibility, for professionals from all over the world, to experience the architectures and urban spaces that are the subject of the competition, without the need to visit the project site directly. Following the limitation of the movements that we are experiencing due to the pandemic, in fact, the importance that digital can have in providing information in real time from any and all parts of the world has been highlighted.
Just in the last year, the need for digital adaptation has been strongly felt in many different sectors and research has found new life for projects that were once perhaps only on a hypothetical basis, but which today are starting to have concrete foundations.
One can think of the ever wider opening of digital archives of artistic works or archival documentation, the concrete creation of apps and navigation sites by museums, the possibility of being able to walk and interact within the virtual museum space, thanks to virtual reality, perhaps in an even more intimate and intense way than analogue reality.
In this sense, starting from the experience of digital relief and restitution developed within the *Reinventing Cities* competition, our reflection invites us to make augmented reality an unprecedented opportunity to expand borders and shorten distances in order to gain knowledge, study and transformation of places, even the most distant ones.
Point cloud or 3D NURBS model, linked by a close relationship of geometric dimensional dependence of the second with the first, are both navigable and interrogable digital environments, but they do not allow us to have the immersive perception of three–dimensional space as we would have in the real site. Although the first step taken with the *Reinventing Cities* experience is a huge step towards the digitization of the historical–architectural heritage, it is desirable that public administrations also proceed towards Virtual Reality, through the inclusion of digitized models in platforms such as Unreal Engine or Revit VR, to ensure immersive design for engineering and architecture firms from all over the world.
The question raises many other questions that research will have to answer over time: which 3D model will be most useful to navigate? How to make the perceptual and sensory aspects as real as possible for a more conscious design? How to solve the problems associated with all kinds of 3D? The point cloud, although dense, is not material and by approaching the architectures, the points and distances between them are identified, allowing a chromatic perception but not of the material. The NURBS model, derived from the cloud, through the still inevitable passage of 2d interpretation on CAD, is not texturized, and therefore, although making the perception spatial and concrete, it does not give us back the chromatic aspects. A mathematical mesh model that can derive from the point cloud, can only partially solve the problems related to perceptual aspects, but the historically treated issues of the discretization of the points and the inevitable loss of detail, especially of the ornamental apparatus, remain. It is necessary that, over time, the public administration aligns itself with the aspects of communication and representation that begin to be typical of museums and archives, realizing that its historical – building heritage (of all eras) is in fact an asset which must be shared in the appropriate manner and for different types of users.

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Authors

Maria Grazia Cianci, Dept. of Architecture, University of Roma Tre, mariagrazia.cianci@uniroma3.it
Daniele Calisi, Dept. of Architecture, University of Roma Tre, daniele.calisi@uniroma3.it
Sara Colaceci, Dept. of History, Representation and Restoration of Architecture, Sapienza University of Rome, sara.colaceci@uniroma1.it
Francesca Paola Mondelli, Dept.of Architecture, University of Roma Tre, francescapaola.mondelli@uniroma3.it

 Isbn 9788835125280

Studies for the Virtual Reconstruction of the Terme del Foro of Cumae

Riccardo Florio
Raffaele Catuogno
Teresa Della Corte
Veronica Marino

Abstract

Resuming the cognitive process started in a previous study of integrated survey and interpretation of the remains of the Terme del Foro of Cumae in the Parco Archeologico dei Campi Flegrei, with this contribution, we intend to set up, a methodology to deepen the investigation already carried out on the current consistencies of the thermal system that, through the preparation of a suitable neural network managed by AI processes and structured for the systematic analysis of differences, is able to formulate reconstructive hypotheses with scientific authority.
By integrating the possibilities of traditional methods of investigation on architectural and archaeological heritage, it will be possible not only to highlight what can be directly observed in situ, but also to enhance traces that are not immediately decodifiable and even latent, automatically emerging as the results of comparative investigations on large amounts of data whose logical structure will be clearly traceable along artificial neural 'meshes' similar to human cognitive processes.

Keywords
cognitive networks, comparative analysis, wall textures, roman baths, Cumae.

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Methodological Reflections

With reference to the cognitive process initiated in a previous study that, starting from integrated survey operations, has produced interpretative results for the archaeological site of the Terme del Foro of Cumae [Florio et al., 2020], it was intended to identify a research methodology that, activating processes of Artificial Intelligence (AI), makes it possible to found reconstructive hypotheses for the Cumaean thermal system on the basis of scientifically validated processes oriented to a deeper and shared knowledge. The aim is to obtain, through the image–based systems and digital visualization technologies, an expanded 'cultural accessibility' for our architectural and archaeological heritage, which allows not only to visit the remains – in situ and/or remotely – and perceive the original consistency with the help of Virtual Reality (VR) and Augmented Reality (AR), already adopted in various important interventions of valorization of sites and museums, but above all to document and communicate in a transparent and accessible way the iter and the 'intellectual integrity' of the research process, allowing users and other scholars to retrace and critically evaluate, contextually to the story of the stratifications in the various phases of life of the sites, the methodological criteria that have guided the reconstructive hypothesis. The use of Information Communication Technologies (ICT) – and the consequent, increasingly refined, possibility of creating forms of digital memory capable of associating a very high density of data to the assets of interest (directly retrievable data overlaid on previous documentation) – is now fundamental in the field of virtual archaeology. Applying to these large masses of information the comparative processes typical of AI, one obtains results whose generative process, clearly traceable along 'meshes' of artificial neural networks similar to human cognitive processes, is accessible and therefore open to refinement or possible corrections. These logical structures, grafting a propulsive field of support for established interpretive tools, lend themselves formidably to the dialectic of continuous informational feed–back necessary for a sustainable predictive formulation of the original sites. By abstracting the multiplicity and continuity of reality, they integrate the methods of traditional architectural–archaeological documentation, allowing to manage and monitor, through representation, not only the virtual reconstructions (and with them the surviving consistencies *in situ*) but the same process of convergence that recomposes the ancient remains, thus bringing scientific authority to digital visualizations, constitutively exposed to the risk of overestimation (unconditional appeal of contemporary media) if not even vacuity for lack of transparency or hyperrealism.

The Study Site and the Neural Networks

The valuable remains of the Terme del Foro were brought to light during an excavation campaign in 1952 at the ancient city of Cuma. The study site is located in the so–called '*città bassa*', "a quarter of Samnite and Roman times that was developed in the flat area that stretches to the east between the acropolis and the slopes that rise towards the *Arco Felice*" [Maiuri 1934, p. 143]. With respect to the original configuration that rose to north of the Temple Capitolium of the Roman city, the Maiuri found in 1958 the rests "of a grandiose thermal building of the I and II century of the empire with vast environments in which the rooms of a calidarium with the apparatus of the prefurnio are recognizable" [Ivi, p. 144].
Among the most indicative factors to guide the dating of the first plant of the Terme del Foro of Cumae archaeologists have identified the correspondence of the planimetric type of the spa complex with the so–called half–axial ring type, widely found in Roman sites of the Hadrianic period. It is clearly legible *in situ*, in the semi–symmetrical articulation of the environments evidenced by a main scenographic axis which, from the entrance vestibule, crosses the intercolumn of the remains (bases and part of the shafts) of two monumental columns in marble extending towards the concavity of the semicircular pool of the *frigidarium* and by a parallel secondary axis along which the concatenation of the warm spaces (*tepidarium, sudatorium, calidarium, praefurnia*) is arranged (fig. 1).
In support of this hypothesis for the dating is the evidence, in the surviving structures, of masonry and flooring techniques, and of materials, typical of the Phlegrean territorial

Fig. 1. Orthographic horizontal section from TLS and orthographic horizontal projection from SAPR of the thermal complex with indication of the original functional destination of the various rooms.

context in the above–mentioned period: at a first reading we find with prevalence the *opus latericium* in *bessales* for the internal curtains of the warm rooms and the *opus reticulatum* with *latericium* reinforcements for the external curtains and for the interiors of the remaining rooms, and also flooring remains in tessellated with a white background. With the aim of intercepting the construction phases of the thermal site to recompose reliably the original consistencies of buildings and wall fragments, integrating the results of archaeological studies conducted, the in–depth study – which is still in progress, at the moment involving the preliminary phase of the research and preceding what will be the application and implementation phase – is aimed at tracing in the remains of the ancient complex, which are considerably lacunose and compromised (also by having been brought to light through a simple excavation operation rather than through stratigraphic excavation), those variations and anomalies that can suggest the stratified structures in the various ages. Through the predisposition of a neural network managed by AI processes and structured for the systematic analysis of the differences – dimensional and density differences of ashlars and mortars, discontinuity of material and facing, texture anomalies (masonry or floor tesserae), etc. – in the subsequent research development phase, it will be possible not only to highlight what is directly related to the stratified structures, but also to the anomalies of the stratified structures. – it will be possible not only to highlight what can be directly observed *in situ* but, by widening in a formidable way the possibilities of traditional methods of investigation and observing the considerable practical advantages offered by the speed of comparison and deduction of the new AI systems, to systematize and enhance aspects and properties not immediately decodifiable and traces even the most latent, such as those material and/or color, automatically emerging as the results of ordered comparative investigations, bringing scientific basis to the hypothesis on the chronological order, up to recompose reliably, and according to various degrees of plausibility because of the convergence of results, the original configurations of the artifacts.

Studies for the Cognitive Analysis of the Terme del Foro

Confirming the indispensability of a hermeneutic action at the base of the hypothesis of virtual reconstruction of the sites, the innovative applications of AI project the methods and the consolidated practices of investigation in the field of ICT and of the complex analysis of large amounts of data, where the experience and the methodological rigor of traditional research are capitalized in favor not only of a high efficiency and speed of results – the automatic recognition of apparently insignificant elements, such as fragments or minimal traces of events, becomes an extraordinary tool to reveal the dating and recomposition – but above all the possibility of making the 'story' and the logical structure of the research accessible simply through the reading (graphical) of the system of relations established by the neural networks. Already in the field of the consolidated methods, the interpretative accuracy of the stratigraphic method is precious for the knowledge of the sites: integrating itself to the phase of excavation, the method contemplates the drawing up of plans of interface for every recognizable stratigraphic unit (overlays), deducing stratigraphic diagrams (matrix) that condense icastically the data found. Other analytical methods, applied in diachronic phase with respect to the excavation, have been using for years deductive processes based on logics structured by input data, 'weighted' relations, levels of investigation, predictive output. Through the mensiochronology, moreover, the multiple input parameters do not acquire meaning in themselves: size and shape of the tesserae or ashlars, their number per unit area, irregularity factors, etc., are considered contextually, as parts of a comparative structure able to develop trend lines for the attribution of chronological bands to the buildings of antiquity. Artificial intelligence algorithms, genetically inclined to the investigation of complexity, allow us to greatly implement these deductive processes, programming operations (of analysis and synthesis) capable of investigating millions of data in all their informative potential (big data systems) in order to have new answers to questions about the past. The cognitive analysis on the Terme del Foro will have to be set up by providing the system with the highest number of data – from those that can be taken *in situ*, by means of TLS and photogram-

Fig. 2. Exemplificative framework of the variations and/or anomalies able to suggest the stratified structures in the various epochs.

metry (orthophotos, photographs, photomosaics, photogrammetries) to those that can be deduced from previous studies or documentation (Roman building systems and those of the following ages, documentation related to wall textures, to the materials used, and building appropriate image–based algorithms capable of recognizing the different periods and reaching, on the basis of thousands of comparison operations (identification of differences, and similarities, between a large number of images, photographs, drawings, historical data) to possible original configurations (fig. 2). If, for example,the experiment were to be applied to the current configuration of the wall textures of the *calidarium* – the last in the sequence of the hot rooms and one of the most affected by wall anomalies and by interventions of reconstruction and/or transformation – the data to be entered would concern the *reticulatum* and the *latericium* of the mixed work detectable in the external curtain, the differences between the pieces analyzed by type of ashlars (*cubilia, bessales*), their ratio with respect to the average size (7x7 cm, for *cubilia*; from 23 to 28 cm of side, for the *bessales*), the variations in the composition of the mortar (with or without volcanic inclusions), the chromatic tonalities of the bricks and their deviation from the uniform orange–pink color, etc. It will also be necessary to document and insert images of the inserts in *opus vittata*, of the mixed *opus vittata* and brickwork, of the brickwork compensations, of different color and workmanship, probably relative to a phase subsequent to the first installation and to obtain data on the cores between the two curtains (prevalently in opus caementicium), investigating the summit wall crests opened by the gradual and progressive deterioration of the thermal remains. Above all, it will be necessary to design the neural network, setting the layers (depth of the network), the number of different features that the network examines at each level (width of the layer), the connections between the data and the layers (weight of the relationships) and opting for a 'convolutional' structure (same pattern of connections between layers) rather than a 'recurrent' one (possibility of 'feedback' between non–adjacent layers) [Hartnett 2019] (fig. 3).

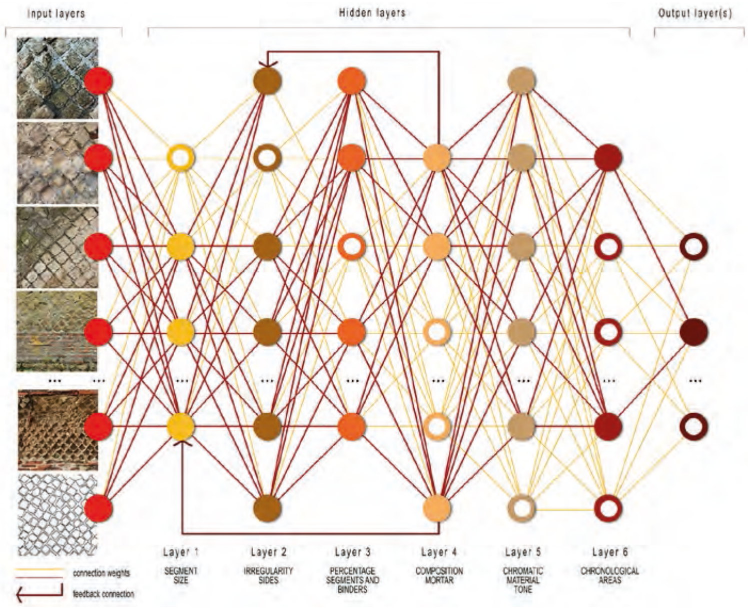

Fig. 3. Simulative hypothesis of the structure of a neural network for the extraction of discriminating features for the original configuration of masonry in *opus reticulatum*. The process assigns differential weights to the connections, distinguishing the differential relevance of the nodes ('full' and 'empty' nodes) for the outcomes; the system also provides feedback connections, filtering out noise and retaining only the most relevant features.

Conclusions

The results of the elaborative operations activated by the neural network in adoption, as well as being archived within the procedural application itself – making permanently available for consultation both the data and the results of the research, as well as the related generative and cognitive process – may be valuable support for a subsequent three–dimensional modeling of the study site. Consistently with the guidelines for a mature virtual archaeology, inspired by criteria analogous to the modern principles of architectural–archaeological restoration [Brusaporci, Trizio 2013, pp. 55-68], the knowledge of the thermal complex, represented in wireframe compositing in order to distinguish the reconstructed parts and allow progressive interpretative updates, will be made accessible and permanently monitored by users in situ and/or remotely, through the adoption of web–based and open source technologies; moreover the applications of AR and the interactive modalities of the digital visualization will be able to associate to the 3D model multiple information and to reveal the relationships between the existing and the reconstructed, favoring the comprehensibility of the ruins.

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Authors
Riccardo Florio, Dept. of Architecture, University of Naples, riccardo.florio@unina.it
Raffaele Catuogno, Dept. of Architecture, University of Naples, raffaele.catuogno@unina.it
Teresa Della Corte, Dept. of Architecture, University of Naples, teresa.dellacorte@unina.it
Veronica Marino, Dept. of Architecture, University of Naples, veronica.marino@unina.it

Isbn 9788835125280

Making the Invisible Visible: Virtual/ Interactive Itineraries in Roman Padua

Maurizio Perticarini
Chiara Callegaro

Abstract

PD–Invisible aims to enhance the archaeological heritage of Padua hidden by urban development. The focus of the process is the creation of an adaptive AR App according to the type of user: professionals and researchers on the one hand and cultural tourism on the other. The workflow identifies a path through the city and connects the artifacts studied by the research; catalogue historical and archival documents; detects the structures through laser scanning and photogrammetry technologies; optimizes the acquired models both from a graphic point of view and through Scan to BIM; develops the AR App in Unity 3D. The research offers further insights assuming the use of artificial intelligence for this type of applications: differentiate the contents of the App according to the user's preferences by comparing the GPS data with those of the detection devices (camera and Lidar).

Keywords
augmented reality, BIM, laser scanning, photogrammetry, artificial intelligence.

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Introduction

PD–Invisible, an abbreviation that stands for 'PaDova INnovative VISions – visualizations and Imaginings Behind the city Learning', is a well rounded project that involved researchers from multiple fields. Archaeologists, building engineers, architects and informatic engineers collaborated for one year with the purpose to make visible what is, actually, invisible to the eyes of many. The project was funded by means of the European Social Fund and the Regione Veneto and included a partnership between the Department of Civil, Environmental and Architectural Engineering and the Department of Cultural Heritage of the University of Padua. The city has a beautiful yet, for the majority, invisible heritage belonging to the Roman age. The urban growth across the centuries and, sometimes, also the lack of attention and care, caused its disappearance. Thus the aim of the research was to promote and valorize these archaeological remains, bringing back their memory and, above all, trying to give them new life. Focus of the project was to create a digital environment suitable and available for both an expert and non–expert public, that provided the visualisation of the outcomes [Johnston et al. 2020; Perticarini, Marzocchella 2021].
The chosen solution included the implementation of an application for smartphone that uses Augmented Reality (AR) and, moreover, Artificial Intelligence (AI). This could enable a simplified fruition of contents, diversifying them depending on the user's intentions and tastes. Multiple data, technical information about the structures, touristic paths and similar point of interests, historical narratives together with pictures and documents, are able to satisfy a wider public in the perspective of a cultural rediscovery of the Roman historical heritage of Padua. The research started with the identification of several points of interest across the city, structures connected by a common past and so linked with a touristic path. The Arena, near the Scrovegni Chapel, is the starting point as it is close to the actual train station, then walking south through the historical centre, along the Riviera dei Ponti Romani, there are Altinate and San Lorenzo Bridges, relevant Roman structures for trades and the economy of the city, hidden under the surface of the street with the tramline.
Finally, reaching Prato della Valle, we can find the foundation system of the Zairo Theatre, also hidden under the water of the canal of this huge and unique square [Bonetto, Pettenò, Veronese 2017]. San Lorenzo Bridge, between these structures, has an excellent conservation status and very positive conditions for the exploitation of the selected workflow. It is located under the street but enclosed in an underground chamber accessible with an old underpass built in the 1950's [Galliazzo 1941; Gasparotto 1951; Carraro et al. 2019]. The division in phases of this research project included the initial data acquisition, the possibility to achieve an accurate 3D model with texture and information and the final AR and AI implementation.

The Case Study

As previously mentioned San Lorenzo Bridge is the case study identified as a starting point for developing research in all its phases and as a key to read for further in–depth analysis of the topic. The first very important operation that provides awareness and understanding of the chosen structure is data acquisition. The acquisition of the preliminar knowledge is then carried out, on the one hand through archival and documentary research to collect all the sources and testimonies regarding the bridge.
On the other hand, the survey performed using laser scanning and photogrammetry to obtain a virtual clone, geometrically similar. These models are the starting point for the subsequent modeling phase. Two different approaches were used: BIM modeling with the aim of providing a container for the information collected, allowing the exchange of data from different sources and the direct connection between different development environments, especially databases. The BIM model was chosen as the invisible backbone of data on which the realistic 3d model lean [Bonetto et al. 2019].

Acquisition of the Invisible Heritages: Archival Memory and 3D Survey for the Digital Reconstruction

Thanks to the permissions given by the following institutions was possible to carry out an extensive archival research: State Archives of Padua, San Gaetano – Altinate Cultural Center, Superintendence of Archeology, Fine Arts and Landscape, Archive of the University of Padua and Eremitani Civic Museum. It was possible to collect all the written and graphic documentation, regarding the main archaeological excavations and finds that during the centuries allowed to add important elements to the study of the Roman Age Padua. Alongside, the geometrical survey on–field of San Lorenzo Bridge covered the acquisition of two different types of survey, one with photogrammetry and the other with laser scanner technology. The Leica ScanStation P20, a time–of–flight scanner, was employed with the support of Leica HDS black/white target for the registration. A total of 18 scans were acquired, with resolution settings of 6,3 mm @ 10 m, and 78 targets were measured. The registration was performed by the software Leica Cyclone with a mean absolute error, checked on the targets, of 3 mm. 24 vertices were measured as reference networks using a total station Leica TCR1201 and thanks to the GNSS was possible to obtain the geographic coordinates. Two photogrammetric surveys were also carried out: the first obtained by means of a Nicon D610 full frame reflex camera with a 35 mm lens; the second by means of two 12 mp GoPro Hero 5 and focal length of 3 mm. The photographs were taken following an orthogonal grid of 50 x 50 cm for each arch of the bridge and the use of GoPro was useful in reaching the narrowest and most inaccessible areas. The point cloud generated by photogrammetry was compared with that obtained by laser scanning and no particular differences were found (fig. 1).

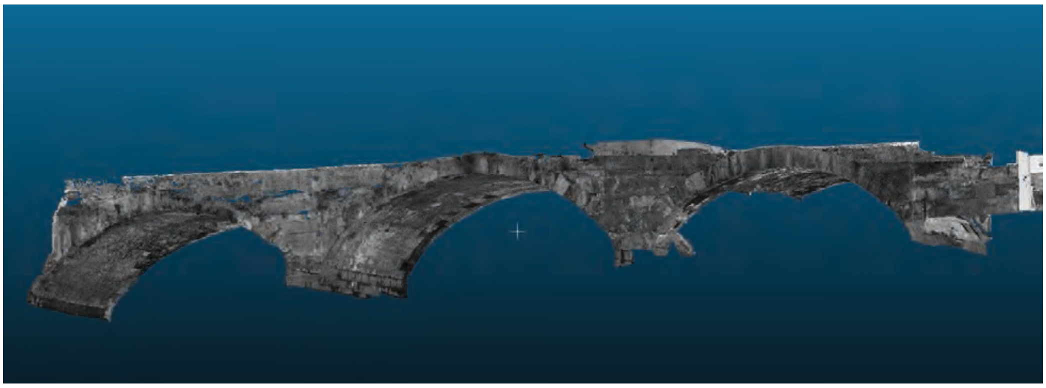

Fig. 1. Point cloud of San Lorenzo Bridge obtained from photogrammetry.

3D Modelling and Optimization for AR of the Photogrammetric Survey

For the creation of the App, a precise workflow was identified to correctly display the 3D models on mobile devices. The first step consists in cleaning the point clouds and creating complex meshes with a high level of detail (the point cloud, the complex mesh and the related texture were obtained with the Agisoft Metashape software). The second phase consists in the optimization of the complex mesh by means of retopology (process that allows to drastically decrease the number of polygons of the mesh, making it lighter and more manageable on all smartphone models) [Palestini, Basso 2017] and by means of the baking of the normal map and diffuse map (process that allows to imprint the level of detail of the surfaces on the texture). For this purpose, the open source Blender 3D software was used for baking operations and the Instant Meshes tool for retopology operations [Perticarini et al. 2020]. Nowadays, with the latest software releases, two retopology systems have been implemented within the software: one based on the Quadriflow algorithm and one based on OpenVDB (Voxel). The third phase involves exporting the models to Unity software and developing the app in AR using Vuforia and Google's ARCore SDK. The App consists of a UI interface that allows navigation within the map and the identification of artifacts along the route; each artifact is visible both on site (through augmented reality) and remotely. It is

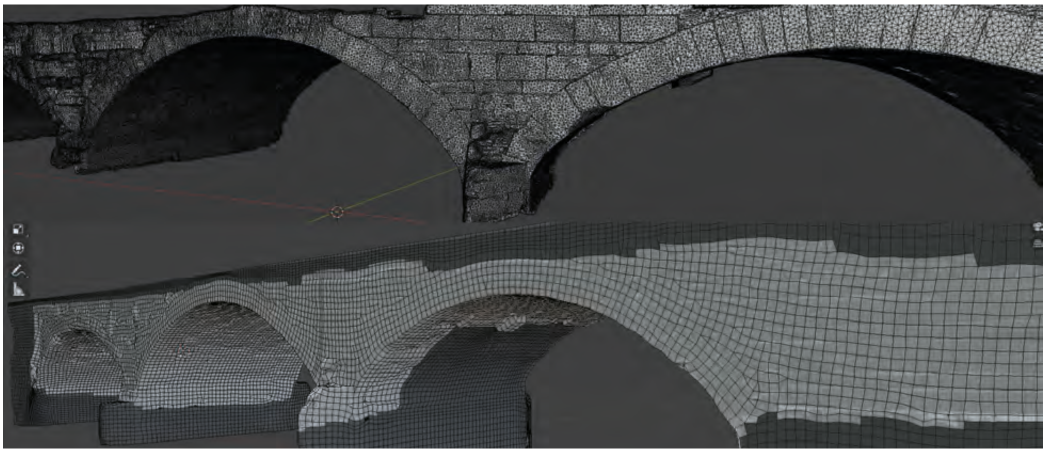

Fig. 2. above, the complex mesh obtained from the point cloud; below, the simple mesh obtained from the retopology operation.

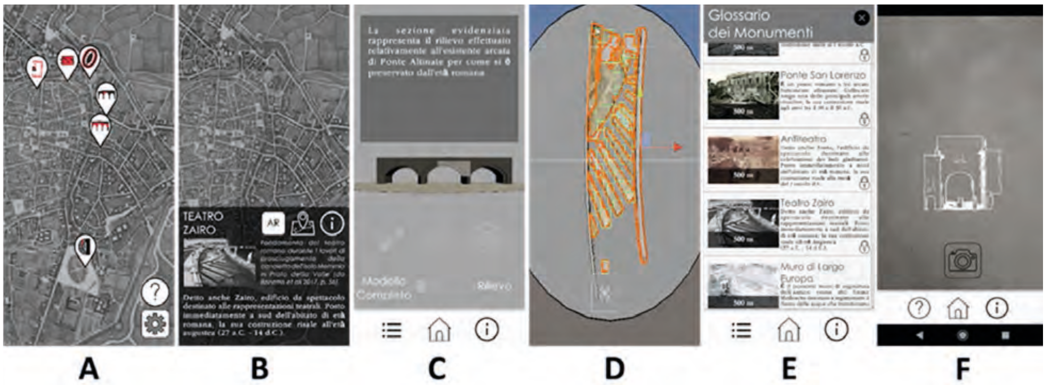

Fig. 3. UI interface of the app. From left: the map, the interactive menus, the 3D model viewer, the glossary and the AR interface.

also possible to view the historical information and the characteristics of the construction elements with a tap on the interactive 3d model, thanks to the implementation of the BIM model on a layer below (figs. 2, 3).

Future Implementations of Artificial Intelligence

A further development of this type of applications could be the use of AI algorithms, in particular machine learning and artificial neural networks, which performs the function of satisfying the needs and interests of the user [Janković 2020]. An example could be to structure an algorithm capable of comparing the data coming from the GPS of the smartphone – relating to the most visited points of interest or the type of gait – with those coming from the camera (the photographs that the user takes most frequently or which artifacts are framed instead of others). Data mining consists in identifying information by extrapolating from large databases and allows, through associations and recurring patterns, to develop an ever–evolving App and an impulse for the user: thanks to the interpolation of data, it offers new suggestions based on the preliminary and continuous learning of the user's tastes [Ye, Qiu 2021]. One of the most used data mining techniques is the neural networks (ANN or NN) adaptive systems that change their structure based on external or internal information during the learning phases. The branch of information technology most suitable for the information coming from the camera is the automatic recognition and artificial vision [Stanisz et al. 2021]. The computer vision system is composed of typical functions that can be differentiated into: image acquisition, pre–processing (resampling, noise reduction, contrast enhancement and space scaling), feature extraction (border lines or ridges), detection or segmentation (small portions of images that are more useful for learning), processing and finally the decision–making process. As for image acquisition, current high–end smartphones are equipped with increasingly advanced sensors; in particular, the iPhone 12 Pro and Pro Max are equipped with a Lidar sensor, the portable version of the Lidar found in self–driving cars for scanning and recognizing objects along the way [Shih, Diao, Chen 2019] [Yao 2020]. The sensor could be an excellent tool to improve the algorithm in the classification of artifacts framed by the smartphone. For the creation of APP of this type, PyTorch is used: a deep learning framework (class of machine learning algorithms) developed by Facebook AI Research (FAIR) group. This open source software allows you to facilitate the development of algorithms compatible with current Nvidia video cards and take advantage of the GPU.

Conclusions

Technological innovations are changing everyday objects into complex intelligent machines. The new sensors for acquiring the surrounding environment and the new processors make it possible to create projects that were unthinkable until a few years ago. it is obvious that often, the use of these technologies has negative sides, especially as regards the use of big data and privacy issues. With greater reason, innovations should be exploited to the maximum for more noble purposes, such as the enhancement and preservation of historical and cultural heritage.

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Authors
Maurizio Perticarini, Dept. of Architecture and Industrial Design, University of Campania Luigi Vanvitelli, maurizio.perticarini@unicampania.it
Chiara Callegaro, Dept. of Civil, Environmental and Architectural Engineering, University of Padua, chiara.callegaro@unipd.it

 Isbn 9788835125280

AR&AI
heritage routes

so–called "Age of Culture" [Schafer 2014], ethical questions arise where Human Computer Interaction can prefigure new reflections and experiments aimed at the interpretation and presentation of cultural heritage. In this context, AI plays a leading role, where users are increasingly accustomed to the use of synthetic and cunning images in the relationship between real and digital [Brusaporci 2019].

Notes

[1] The research has received funding from the Italian Government under Cipe resolution n.135 (Dec. 21, 2012), project INnovating City Planning through Information and Communication Technologies (INCIPICT).

[2] MEC, formerly mobile edge computing, refers to the enabling technologies that provide computing capabilities and service environment at the edge of the network [European Telecommunications Standards Institute (ETSI) White Paper].

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Authors
Stefano Brusaporci, Dept. of Civil, Construction–Architectural and Environmental Engineering, University of L'Aquila, stefano.brusaporci@univaq.it
Pamela Maiezza, Dept. of Civil, Construction–Architectural and Environmental Engineering, University of L'Aquila, pamela.maiezza@univaq.it
Alessandra Tata, Dept. of Civil, Construction–Architectural and Environmental Engineering, University of L'Aquila, alessandra.tata@graduate.univaq
Fabio Graziosi, Dept. of Information Engineering, Computer Science and Mathematics, University of L'Aquila, fabio.graziosi@univaq.it
Fabio Franchi, Dept. of Information Engineering, Computer Science and Mathematics, University of L'Aquila, fabio.franchi@univaq.it

 Isbn 9788835125280

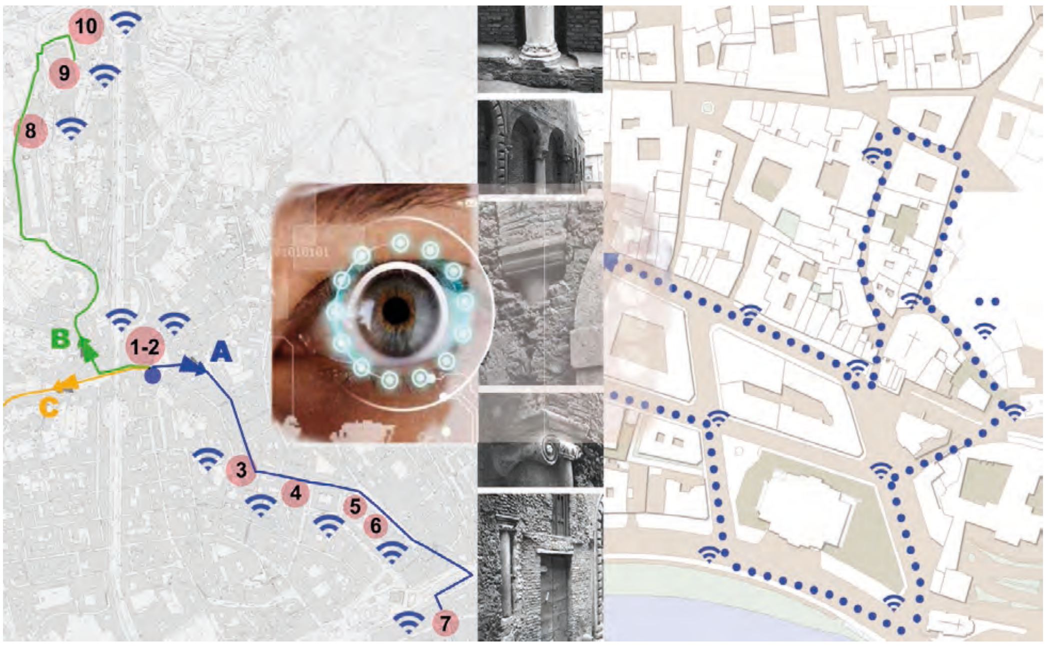
Advanced Practices of Augmented Reality: the Open Air Museum Systems for the Valorisation and Dissemination of Cultural Heritage

Gerardo Maria Cennamo

Abstract

This paper aims to explore the broad topic concerning the use of virtualization technologies in order to earn knowledge of the cultural heritage and it's dissemination. The activities aimed to develop the use of these advanced technologies, in the archaeological and architectural heritage promotion, are constantly evolving. This is the case for the museum fruition, that was confined to places of conservation and contemplation until a few years ago, but now exportable to whole urban sites (open air museums) thanks to the support of the virtuality that introduce to immersive learning paths. Very important resources in the cultural heritage valorisation process are the fruition improvement and the active involvement of the guest through the use of immersive paths, both pedestrian and vehicular.

Keywords
cultural heritage, representation, museum experience, advanced technologies, augmented reality.



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This paper is part of a broader research work, already anticipated in other scientific discussions dealing with the use of the reality's virtualization technologies applied to the enhancement of the cultural heritage; this technology represent a powerful tool to improve knowledge, learning and dissemination supports, but it only should be considered effective when its use is codified through rigorous approaches.
Strategies for knowledge disseminating through efficient and enjoyable communication approaches, include diversified levels of in–depth analysis (such as those offered by advanced technologies in the fields of surveying, post–processing and representation). These strategies take on an indispensable role as support of the scientific research methodologies in the archaeological and architectural heritage activities, sometimes overcoming the instrumental value and configuring themselves as an individually recognizable step of the research process.

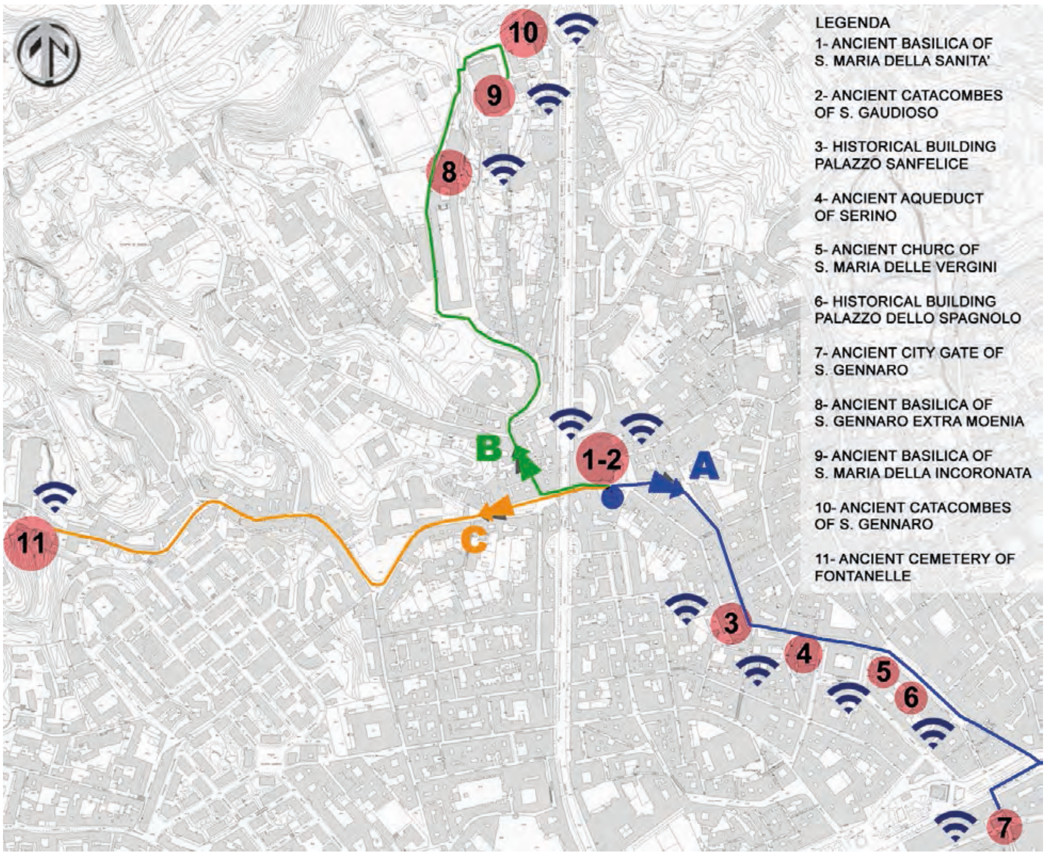

Fig. 1. Open air museum: experiment of immersive AR path, Naples Rione Sanità

The gradual development of the digital virtuality, which began in the 70's of the last century [1], has had a large spread that was proportional to the constant migration of the IOT technologies towards easer platforms, widely usable and accessible to most people. This defines a widespread acceptance of a new transmission code of informations or a new system of symbols, typical of the virtual environment; already considered by the researcher M. Forte in 2004 – with some residual doubts – is the exponential development of widespread applications to be integrated into exhibition tour for museums, widely usable by all the people and not the prerogative only of a specialist users [Forte 2004].
The full diffusion of the digital and simulation technologies, now achieved, obliges us to share this new informations transmission code, that is based on various cybernetic interactions [2] and is alternative to the natural one that is based on known spatial and perceptive rules; already at the beginning of this millennium, some researches took into consideration this possibility, resulting from the diffusion of virtual reality and its dynamics of information exchange, from which it would emerge "un nuovo codice percettivo dello spazio e del tempo in cui la prospettiva, insieme alle operazioni mentali di temporalizzazi-

one e spazializzazione che essa presupponeva, viene definitivamente messa in discussione e, divenuta un'alternativa tra le altre, si de–oggettivizza" [Pecchinenda 2003, p. 49].
By circumscribing the argument in the interests of this study, we can be maintain that the main purpose of a digital processing is to increase the perception capacity (of the object itself as a cultural asset) and it's resulting semantic charged. In other words, the digital transposition of a cultural asset introduces a complex process whose effects include a extensive review of the asset itself for its reinterpretation and dissemination in a virtual way. We can assumed that the studying, analysing and processing activities applied to the cultural asset itself for the purpose of its transposition into a digital way, can bring out a features (and their interpretations) alternatives to those obtainable from the approach not aimed at simulation activities in a virtual environment. In this way, a rigorous approach to the cultural heritage produce multiple variables of knowldge: "L'epistemologia del virtuale suggerisce alcune riflessioni circa lo scambio e la geometria di informazioni fra reale e virtuale, fra soggetto e oggetto della fruizione culturale nell'ottica di una nuova musealizzazione virtuale di dati ed informazioni culturali" [Forte 2004, p. 429].
By spreading this considerations, it is clear that the need to code a rigorous syntax not only of the digital models (which are the basis of augmented virtual reality) rather of the entire procedure of developing and managment in the virtual environment, still finds ample space in the scientific debate.
To date be lack a univocal code, a procedural guidelines to refer to develop these specific activities. This situation represents an anomaly not only of epistemological value but also normative one, that we must be considered as any approach to the cultural heritage is, to date, regulated both in terms of methodological aspects and in terms of the definition of the outputs.

Fig. 2. Open air museum: augmented contents (Palazzo Sanfelice, Rione Sanità).

The analysis procedures and surveying systems are, for example, rigorously codified, the methodologies of approach to study, research and planning recognized and internationally shared, the typologies and number of the outputs to be produced are well regulated. Even the use of digital in the AEC scope, is harnessed within a regulatory system that encodes and regulates the processing phases [3]: the processing of technical and designing data into the BIM process, are governed by regulatory and unifying rules issued both by the EU and by the nationally jurisdiction [4]. It seems to slipping away a shared regulation, for the approach and implementation method, especially in the direction of the archaeological and architectural heritage, specific for the virtually tools.
To better clarify the concept, we should be remember that the virtualization of works art or cultural assets in the museum buildings is a well–established practice that finds excellent examples; there are many important museum organizations that have elected the virtuality as the ordinary modus for the public offer of their heritage. The most usual use, in this case, is the virtual reality (VR). On the other hand, the possibility of converting entire areas or urban districts of historical and archaeological interest where to develop immersive paths of perception through digital reality, makes use of augmented reality (AR) [5].
Semantic issue: the activity already described is not free by some aspects that still need to be explored. For example, we can considered, in the case of the 'museum translation' of entire sites through the instruments of the augmented reality, that the semantic weight bring out of this experience have a greater concreteness than a similar one lived in a completely virtual environment. This because the digital transposition of scientific contents (so–called augmented contents) finds a direct and one–to–one correspondence with the real context, developing with it continuous interactions and exchanges of information that are not expected due to the

multiple variables introduced by the guest himself. Instead, the many museum organizations that offer visiting through virtual reality, translating the visitor into a concluded virtual environment with a programmed digital dynamics (both for the object, for the work art or for the archaeological site) offer digital experience that, in proposing a completely virtual environment, impose precise conditions so reducing the uncontrolled variables.
The virtual environments: we can speak about "territorial systems of cultural heritage" understood as areas with specific features. In the open–air museumization experiments, the important possibilities offered trought the simulation technologies, in terms of reality understanding with the support of the virtually reproducing, appear today as a overcome frontiers through the transposition of the visitor from an external dimension to a participatory one. This opportunity must be understood not only as the ability to interact with the digital model and as a conferment of an active role to the viewer but, rather, as the induction of a concrete participatory perception in a digital reality. We talk about a digital perceptual system in which the observer not only follows preordained paths (mental, visual, exploratory or perceptive) but in which he can freely exercise arbitrary choices, placing himself in an active one–to–one relationship with the virtual environment: "In RV tutte le informazioni sono interconnesse in uno spazio 3D; una ontologia della connettività implica una causalità mutuale: attore ed ambiente si modificano reciprocamente creando nuova informazione" [Forte 2004, p. 430].
The user of immersive knowledge paths, supporting by augmented reality, can follow preordained patterns but also can activate alternative behaviours, creating new conditions during the experience of exploration: in any case, the cybernetic relationships that are triggered during this experience are multiple and unpredictable, precisely because they include a participatory–active role of the visitor within the fruition and learning environment: "l'animale umano, grazie al fatto che interpone uno schermo semiotico fra la mente e l'ambiente esterno, può […] guidare dall'interno la percezione, liberandosi dall'influsso diretto dell'ambiente esterno" [Cimatti 2000, p. 246].
In this time the so–called open air museum use [6], that is enjoyed outside of the architectural envelopes and supported by new perceptive tools based on integrated digital systems, becomes a concrete opportunity in the purpose of cultural heritage dissemination and deepening.
Thanks to the support of GPS systems it is possible to develop dynamic paths of perception of the archaeological and architectural heritage, integrated by augmented reality applications; this change allow immersive experiences of knowledge, reconstruction and stratigraphic reading not only of monuments but of entire historical sites. This approach, implemented trought an active involvement of the visitor during the immersive augmented reality paths, can be enjoyed for pedestrian both vehicular itineraries, representing a very relevant resource in terms of opportunities to valorisation the cultural heritage. Very interesting for the research purposes are also the replicable experiments about homogeneous territorial areas, with replicable characteristics, such as the Jewish ghettos within the main historical cities. Two researches are underway, one in Rome in the Jewish Ghetto area and the other in Naples in the Sanità district.
The first sample develop an experiment with the pedestrian path. In this mode, the technological support must include specific viewers for the augmented reality. These devices are nothing more than glasses equipped with high–definition transparent lenses that allow the wearer to benefit from augmented reality applications through a holographic interface with which to interact through gaze, hand gestures or voice. In order to function correctly and guarantee the recognition of the augmented contents, it is necessary to associate spatial references (target) to the context, in order to obtain a system that guarantees the correct overlap between physical environment and digital reality.
The second sample experiments a vehicular path, enjoyed from inside the vehicles such as a taxi, bus, city sightseeing or other. The guests on board will install an application on their smartphone that will allow them to enjoy the augmented contents. The application will activate the geo–referencing system for the tracking of the visitor's position along the path, while a Bluetooth device will allow activation of the digital contents when the user arrives near the site or point of interest.

In order to make the synchronism between the approach of the visitor and the delivery of multimedia contents reliable, the interaction system is entrusted to particular transmitters (beacon) which, positioned near the points of interest, send information managed by the application pre–installed on the guest's devices.

Conclusion

The studies in order to codifying and to controlling the potential of the reality simulation applications about the archaeological and architectural heritage, are constantly evolving, which confirming the important opportunity linked to the new frontiers of approach in this specific scope. Although in a simulated way, these processes have their main objective in the description of the cultural heritage within its site of origin; in addition to the strong contribution carrying out from the technologies, we must remember that the effectiveness of these systems is based on a methodologically correct approaches in the phases of investigation, analysis, surveying and processing, which are typical of the representation sciences. About the identification of precise guidelines, useful to implement the correct use of these technologies in order not to 'succumb' to the digital and virtuality potential but, vice versa, to direct their contents in the correct direction of a scientific approach, we must to consider the possibility of defining new syntactic codes within the mechanisms of perception and representation, as recently observed by Alberto Olivetti [7]: "Dovremmo riflettere su quanto sia cambiata la dimensione della percezione e la consapevolezza diffusa del passato, del presente e del futuro. Alludo alla dilagante rapidissima estensione dei mezzi virtuali di tipo informatico che hanno profondamente inciso su quel rapporto di spazio e tempo che forma l'endiadi entro la quale passato–presente–futuro agiscono poiché il tempo, in una dimensione virtuale, annulla le categorie di spazio e tempo quali erano state elaborate solo fino a ieri".

Notes

[1] The first virtual reality system is the one created in 1968 by Sutherland and Sproull, cfr. Biocca, F., Delaney, B. (1995). Immersive Virtual Reality Technology, in: *Communication in the Age of Virtual Reality*, Hillsdale: Lawrence Erlbaum Associates.

[2] Cfr. https://www.treccani.it/enciclopedia/cibernetica, definition by Treccani online: Cybernetics, a discipline that focus the unitary study of processes concerning 'communication and control in animals and machines'. It can also be defined as the general study of highly organized complex systems, regardless of their nature.

[3] The acronym AEC (Architecture Engineering Construction) identifies the building sector supported by IT approaches. The reference literature is very large and finds important interests in the area of the representation.

[4] In Italy: the law about BIM is the D.M. 560/17; the regulation about BIM is the UNI 11337–7.

[5] A brief definition of augmented reality by Treccani online cfr. https://www.treccani.it/encyclopedia/ augmented–reality: virtual reality technology (AR) through which a digital contents are added to the real environment. In opposed to the concept of virtual reality (VR) which develops fully virtual environments.

[6] The reference is to conversion of full historical sites in open–air museums. On the subject cfr. Cennamo, G. (2018).

[7] Cfr. Olivetti, A., Stati Generali della Memoria, Università Telematica Internazionale UNINETTUNO, Roma, 2020.

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Author
Gerardo Maria Cennamo, Engineering Faculty, Università Telematica Internazionale UNINETTUNO, g.cennamo@uninettunouniversity.net

 Isbn 9788835125280

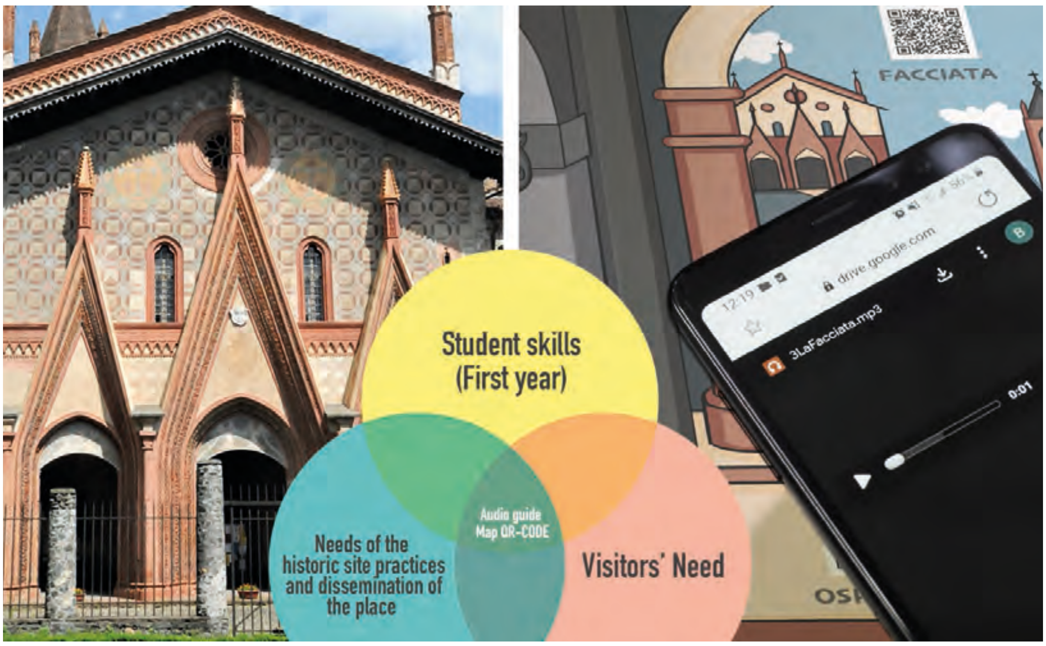
The Use of AR Illustration in the Promotion of Heritage Sites

Serena Fumero
Benedetta Frezzotti

Abstract

The course of Performative Techniques in Visual Arts (2020-21 edition) at Libera Accademia d'Arte Novalia revolved around a project which saw students actively involved in the promotion of a local heritage site: the Precettoria (Abbey) of Sant'Antonio di Ranverso (Province of Turin). Despite its cultural relevance this site is little known, although the last few years saw an intense campaign for the promotion and restoration of the complex. The project completed during the course is part of this effort and the management of the site has been involved in its completion.

Keywords
augmented reality, heritage sites, Accademia Novalia, educational services.



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Goals and Methodology

Precettoria of Sant'Antonio di Ranverso:
Among the sites managed by the Fondazione Ordine Mauriziano [1], we decided to focus on the Precettoria of Sant'Antonio di Ranverso because this complex, located at the entrance of the Susa Valley [2], is a prestigious site whose late–Gothic architecture and rich and wonderful frescoes bring us back in time to the age of the Duchy of Savoy, between the dusk of the Middle Ages and the beginning of the Renaissance.
The social and historical relevance of the complex of Ranverso during the medieval period originated in 1188, when the Duke of Savoy offered the site to the Hospital Brothers of Saint Anthony. The members of the religious order hosted pilgrims and patients suffering from shingles (commonly referred to in Italian as *fuoco di Sant'Antonio*, meaning 'Sant Anthony's fire') and, later, from the plague. The Precettoria was conveniently located on the Via Francigena, the pilgrim route leading to Rome and some of the foremost religious sites of Christianity. Over the centuries, the entire complex has been rebuilt several times, while the church was completed during the last three decades of the 15th century, commissioned by Jean de Montchenou, who was named Prior in 1470. Back then, the complex included a hospital (of which only the façade is surviving), the church, and the Precettoria building. Of particular importance are the frescoes painted inside the church, depicting stories from the life of Saint Anthony the Great, the life of the Virgin Mary, the Passion of Christ, and the life of Saint Blaise of Sebaste, painted by Giacomo Jaquerio and his atelier in the first quarter of the 15th century: they are a true masterpiece of the International Gothic.
At the end of the 18th century, S. Antonio di Ranverso presided over a vast territory and, judging from the number of rural buildings, the surrounding area must have been considerably populated. By the time of the suppression of the Order of Saint Anthony in 1776, the territory administered by Sant'Antonio di Ranverso included almost a quarter of the area of the town of Buttigliera Alta, plus four farmsteads: all buildings and the land were assigned by the Pope Pius VI to the Ordine Mauriziano, and now belong to the Fondazione Ordine Mauriziano, a foundation who converted the site into a museum and is now safeguarding and promoting it.
Despite its cultural relevance, this site is little known: this is due to the lack of touristic promotion (which started only very recently) and the location of the Precettoria, which is currently cut off from public transportation. The restoration of the church, carried on between 2015 and 2017, has marked an important step: the lighting inside the church has been entirely redesigned, and a ticket office and a bookshop were added.
From the opening of the site to the public in June 2017, special efforts have been made to promote the visibility of the Precettoria, to establish educational services tailored for different visitors (from schools to families), and to use social media to reach potential visitors both in Italy and abroad.
In this framework, the work carried out as part of the Performative Techniques in Visual Arts course at the Libera Accademia d'Arte Novalia [3], in collaboration with the site management, was marked by the signing of an agreement between the parties involved to grant the stu-

Fig. 1. The site, seen from the Via Francigena.

dents access to all the available study material and total freedom of action inside the complex. The project was carried out in two phases. Phase 1 was carried out on site, to assess the true extent of the tour of the entire complex – and not just of the church: it was immediately clear how an easily accessible audio–guide was key to fully understand the area and its surrounding, including the exterior of the building facing towards the Via Francigena, next to the hospital's façade.
Beyond a guided tour led by a museum curator, who is not always available, the only sources of information for the visitors were a few info pillars located inside the church, under the portico, and inside the cloister. We decided to create educational content and made them available to visitors; considering that the site is mainly toured by families with children, we aimed at engaging that specific audience.
Phase 2 was a detailed survey of the needs of the site, of the Accademia didactics, and of the users, which we can summarize as follows:

Precettoria of Sant'Antonio di Ranverso:
• Create an interactive guide available during the tour of the site;
• Minimize costs;
• Design an object for the museum shop;
• Not having info pillars, panels, or other structures installed on site.

Accademia didactics:
• Enhance the students' skills: the Accademia focuses on art techniques and the history of art, but not on coding (any need for that must have been outsourced, reducing the involvement of students in the project).
Users [4]
• Explore the site;
• Minimize costs;
• Not having apps installed on personal devices (because data plan costs, storage space issues, etc.)
• Engage children without resorting to tablets or mobile devices.
The data we collected have been analysed and used to evaluate the potential of different solutions, like info pillars with NFC chips, VR, AR with illustrated markers, AR with the mapping of existing elements to be used as markers, an e–book or in–app guide, and AR with QR codes. All potential solutions and technologies were tested and analysed by the students, as summarized in the following table:

		Guides	Low cost (for the site management)	Not having apps installed on personal devices	Low cost (for users)	Children	No info pillars needed	Shop
Info pillars with NFC chip	x	x		x	x			
VR					x			
AR with illustrated markers		x			x			x
AR with mapping of existing elements		x			x		x	
E–book or in–app guides	x	x			x	x	x	
AR with QR code	x	x	x	x	x	x	x	x

As clearly shown, the only choice meeting all the criteria proved to be an illustrated map with QR codes linking to files from an audio–guide recorded by the students.
The project was carried out in 5 steps:
1) Production of all the assets needed to complete the project. First of all, the students visited the Precettoria and identified 8 points of interest along the visiting route, based on their relevance to the learning process related to the site: the goal was using them to build an itinerary both inside and outside the complex, to explain in very simple words the spirit of the place, the emotional journey of the pilgrims, the everyday life of the monks, and the work of the atelier of a major painter on the 15th century frescoes.
2) Writing the audio–guide text and recording it. The language used is precise but accessible to everyone, including families with children.
3) Designing the map. We opted for an A4 size prioritizing illustrations, lowering printing cost but also making it user–friendly even for children. The map can be folded and held easily with one hand while holding a mobile device in the other.
4) Testing the map. As soon as the layout was ready, the students were asked to print a copy of the map and test the QR codes in low light conditions to ensure that they would work inside the Precettoria.
5) Production of the final map file, ready for printing.

Discussion

The AR and VR technologies are more and more widespread today, so there was much discussion about the opportunity of resorting to a simpler AR technology such as QR codes for this project, and if that might have led to a greater risk of obsolescence. The choice of QR codes was made to increase the degree of independence for students working on the project but also with the visitors of the Precettoria in mind: a comparatively low–tech product is far more suitable for their audience.

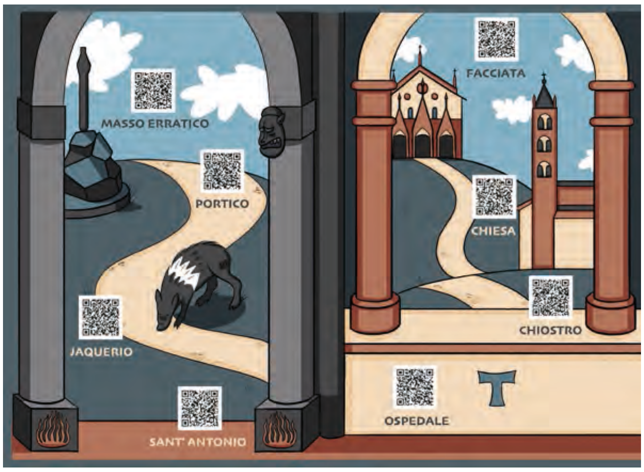

Fig. 2. The first map selected for testing.

It took almost 10 years for QR codes to become widespread to the point where the vast public is now able to recognize them and use them with no need for specific instructions. QR codes are now printed on billboards for supermarkets' promotional sale, on school books used in primary schools, and even on menus, a growing use seen during the Covid–19 epidemic. Most of the mobile phones today don't need a specific app to read them: they can be read using a phone camera. This assessment led to the conclusion that QR codes are familiar and easily accessible to a vast and diversified public, while AR markers require a specific app and VR is not suitable for children under the age of 12 (and can be unpleasant for many adults). QR codes might also eventually be integrated with NFC chips for greater accessibility for visually impaired visitors. Furthermore, this technology is so common that the first survey about the implementation of QR codes in museums, promoted by the SMartArt [5] project, dates back to 2013. We can safely assume that QR codes will be the standard for museums in

the near future. The main innovation in this project is where the QR codes are printed: not on info pillars or panels but on an illustrated map, a physical although low–cost object made more attractive by illustrations. The map is able to draw the attention of the visitors who, when they return to their homes, are still able to maintain a dialogue with the site thanks to the audio contents, which can be accessed and listened to anytime they want.
The students were considerably engaged by this project. Opting for a technology such as the QR code, so easy to use, didn't affect the visual and creative design but only the potential need for coding. The quality of the final works has been consistently high. Unfortunately the visitors' feedback has been delayed by the measures and restrictions in place during the current Covid–19 epidemic.

Conclusions

This project has proven extremely beneficial both for the didactics and for the Precettoria. We hope that the low cost and the relative ease of content production in this format will encourage a similar approach in many other heritage sites which, similarly to Sant'Antonio di Ranverso, are maybe little known but of great historical and artistic importance: similar contents can be implemented where a visiting itinerary is missing or to promote itineraries tailored for families or visitors belonging to specific categories. Regular updates will also help form a long–lasting relationship between the site and its visitors.

Acknowledgements

Our heartfelt thanks to the Precettoria of Sant'Antonio di Ranverso and the Fondazione Ordine Mauriziano for their support, but also to the students and management of the Libera Accademia d'Arte Novalia for carrying out the project despite the Covid–19 emergency and the sudden switch to remote learning.

Notes

[1] The site of the Precettoria belongs to F.O.M. Fondazione Ordine Mauriziano, a foundation whose aim is to protect and promote the Precettoria of Sant'Antonio di Ranverso, the Abbey of Staffarda and the Palazzina di Caccia of Stupinigi, which is a UNESCO World Heritage Site.

[2] In Buttigliera Alta (Province of Turin).

[3] The Libera Accademia d'Arte Novalia of Alba (https://novaliaarte.com/).

[4] Users' needs have been assessed based on the information collected from visitors and by creating fictional 'Personas'.

[5] QR–CODES in MUSEUMS, http://www.smart-art.it/qr-codes-museums/ (23 February 2021).

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Authors
Serena Fumero, Libera Accademia d'Arte Novalia of Alba, Precettoria of Sant'Antonio di Ranverso (Educational Services)
Benedetta Frezzotti, Libera Accademia d'Arte Novalia of Alba, Studio Platypus – Milan, benedetta.frezzotti@studioplatypus.it

 Isbn 9788835125280

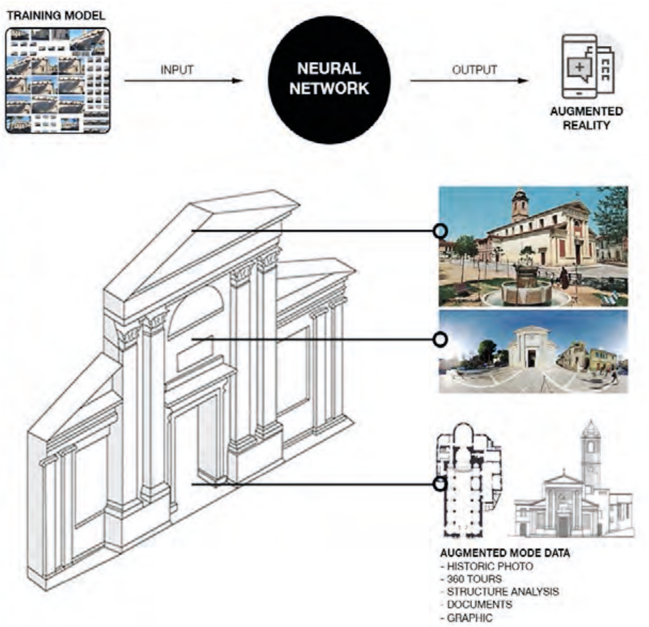
The Sanctuary BVMA in Pescara: AR Fruition of the Pre–Conciliar Layout

Alessandro Luigini
Stefano Brusaporci
Alessandro Basso
Pamela Maiezza

Abstract

The project presented here is addressed to the documentation, the investigation of architectural values and their valorization through an application of Augmented Reality technologies enhanced by an AI based tracking application of the Sanctuary Basilica Madonna dei Sette Dolori (BVMA: Beata Vergine Maria Addolorata) in Pescara. The workflow foresees the use of the numerous images taken for the phases of photogrammetric acquisition of the artefact and images taken from the visualizations of the cloud of laser scanner points in order to carry out the "education" phase of the AI software (so that the program can store the greatest number of images for a self interpretative reconstruction of the geometries). The AI data will then be used as a tracking structure for the AR overlay of the digital model on real space, all through a webXR application usable from any device (HMD, desktop or mobile).

Keywords
segmentation, virtual heritage, machine learning for heritage, augmented reality for heritage, deep learning.



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Introduction

The project is to be included in the context of cultural heritage enhancement practices, through the use of digital technologies of three–dimensional modelling, Augmented Reality and Artificial Intelligence. The aim of the project is the development of an AR navigation device that allows the interactive visualisation of the pre–conciliar configuration of the church in real time. The contribution of digitisation in enhancing heritage and supporting our awareness of our history is significant (Cameron, Kenderine 2007; Pavlidis et al. 2007; Pescarin 2016; Luigini 2019), and AR technologies add the plus–value of a natural fruition, compared to what happens with VR.
The *Sacrosanctum Concilium* of 4 December 1963, drafted within the *Second Vatican Council* held between 1962 and 1965, introduced important innovations concerning the Catholic liturgy and liturgical space that started an important season of adaptation of the existing churches, especially in the area of the presbytery.
The XIX National Eucharistic Congress held in Pescara in 1977 was the opportunity for the upgrading of the Church of BVMA, and the main interventions were: the removal of the balustrade that bounded the presbytery, the replacement of the altar with a frontal altar and the removal of the ambo at the height of the first span, with the consequent placement of the current ambo on the presbytery. The artistic value of the new artefacts does not coincide with those replaced, and so the project to make the early twentieth–century configuration usable again is motivated by the need to restore an architecturally significant configuration to the church.
The church, built in several stages from the second half of the seventeenth century until the mid–nineteenth century with the construction of the bell tower, is in the shape of a Latin cross with three naves covered by elliptical low domes, and a tripartite façade with a pediment in the centre supported by two pairs of pilasters and two side wings with another two pairs of pilasters. The digital reconstruction work will concern, in particular, the apse area and the façade, the latter plastered in the mid–twentieth century and recently exposed (fig. 1).

Fig. 1. Lateral section of the church obtained from the point cloud of the laser scanner survey.

Artificial Logic Construction: State of the Art

AI allows computers to imitate human cognitive processes in order to configure a logic in which 'learning' and 'solving problems' automatically brings considerable benefits in many application areas, where its consistent use can be found in Computer Vision, such as Rendering, Facial Recognition, Video Post Production, but also in 3D survey procedures, laser scanning or photogrammetry, applicable in disciplines such as Geomatics and Architecture: multidisciplinary studies, both theoretical and practical, are progressively opening towards spheres aimed at the analysis and dissemination of Heritage, clearly involving the transversal use of new media, such as AR. New ML technologies and AR dynamics could improve the development of applications that can be exploited in education or Heritage enhancement projects, amplifying space/user interactivity. In the future, a progressive development of smart applications is therefore envisaged, combining the new technologies of AR, DL and Semantic web focusing on the recognition of objects in different conditions, even very complicated ones, retrieving relevant information through semantically linked open data and interactively augmenting this information in real time in a real perceptual environment [Lampropoulos et al. 2020].

AR and AI effectively cooperate together, making them the two most promising technologies available to mobile application developers without the need for complex programming steps, since machine learning models use self–generated data from which patterns and correlations are learned, and AR, capable of merging physical environments with digital content. Thanks to the integration of the two technologies, the credible superimposition of digital elements on physical objects also makes any element captured, subject to any kind of investigation, questionable through an accurate digital segmentation self–recognised by the computer. This opens up exceptional potential uses by providing new ways of interacting with the physical and digital worlds. The calculations in question refer to the Deep Neural Network, the term 'Deep' expresses the function in which multitudes of data–layers, similar to the human neural system, transform the input data to generate solutions by means of repeated processes of automatic compilation. In short, it is a form of automatic learning that learns to recognise the real world by identifying it through nested hierarchies of visual samples in which each individual conceptual model is defined as the result of other abstractions.

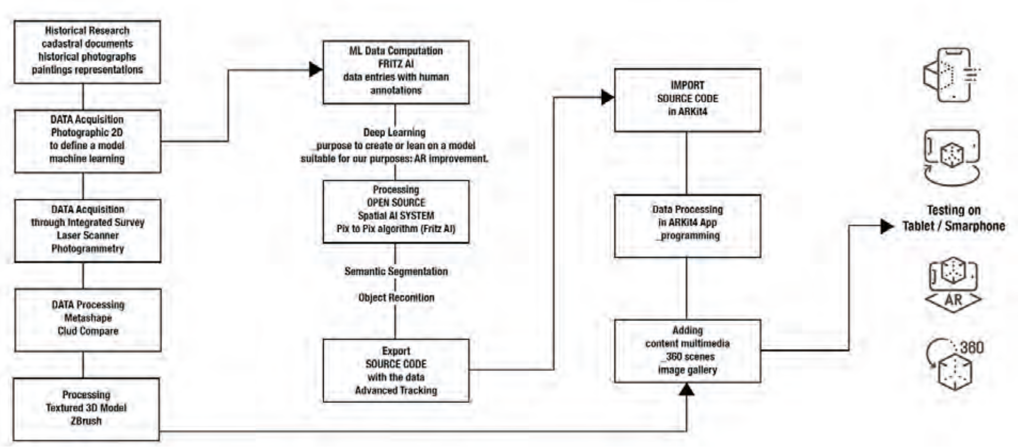

Fig. 2. Complete workflow of the search process: from document search to AR application.

The Application Case Study

This research aims to employ the open source tools available on the web for AR technology with the integration of some algorithms that allow editing of AI–based space3D tracking: a polygonal model of the church of BVMA in Pescara, reconfigured from a previous laser scanner survey according to the latest sculpting modelling techniques, is visually superimposed through an App for smartphones that exploits the most popular AR systems with the support of artificial intelligence according to the preconfigured FRITZ_AI model, to offer a tour that can show, with simplicity and immediacy, the architectural evolution of the church assuming also the previous historical variants (fig. 4). The workflow (fig. 2) can therefore be divided into main phases when the ML procedure employed foresaw the use of numerous images taken from the photogrammetric acquisition and images taken from the post visualisations of the cloud of laser scanner points.
The AI data was then used as a tracking structure for the AR overlay of the digital model on real space, all via mobile devices.
In order to allow in AR visualization a credible correspondence of the model, we opted for a polygonal modeling that exactly traces the point cloud. An HD polygonal model was obtained thanks to the use of the open source software Cloud Compare, through the reconstructive algorithm of the Poisson Surface Reconstruction plug–in , which generated a mesh capable of credibly tracing, based on the parameters entered, the shape that the point cloud assumes from the laser scanner survey starting from its maximum density. In order to obtain a versatile polygonal model suitable for an easy transposition on popular virtual platforms that support AR visualization, it is necessary to optimize the mesh in high resolution deriving from the survey by means of auto–retopology and to generate the UVMap useful to support the textured mappings that replicate the hyper–detailed model, which currently

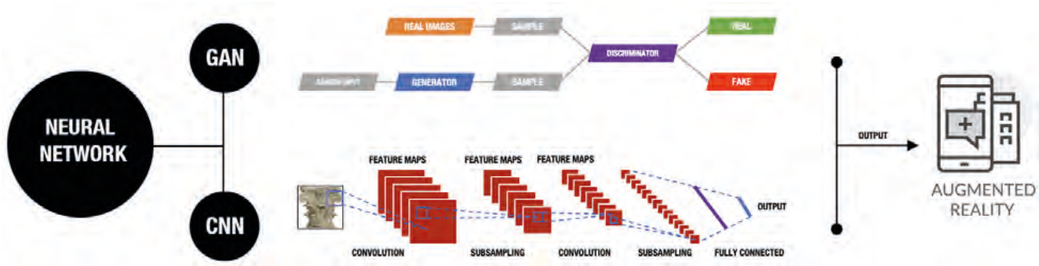

Fig. 3. Synthetic diagram of the functioning of GANs, used for tracking, and CNNs, used for semantic segmentation.

consists of a poly count too high to be managed on mobile real time rendering platforms. The operations are carried out with Zbrush, an artistic sculpting program often used in the workflow for the 3D management of hyper–realistic architectural assets [Trizio et al. 2019]. Machine Learning can currently be considered an indispensable tool for improving AR apps. The case study used the 'FRITZ–AI_ML Platform' , an online resource that, by providing AI–based 'training' models, allows developers to use image datasets immediately for production without the need to compile any code. Both Core ML and TensorFlow Lite models are automatically generated, making it easier to develop apps with ARKIT4 and ARCore functionality. Through a univocal interface and a progressive and guided workflow, it is possible to choose the type of model you want to use right from the start, based on the functions supporting the App, including Object Detection, which identifies objects in an image and draws a bounding box around them to make them interrogable, Pose Estimation, which predicts the position of specific key points in an image to perform precise tracking; Image Segmentation, which enables automatic recognition of framed objects using pixels; or Model Labeling, which can recognise people, places and things based on an ML model trained on millions of previously 'labelled' images. For the generation of any model, however, it is necessary to load a Data Set of images functional to the AI training. There are several types of external collections currently in use, such as Oasis Dataset, but for an optimal result the best solution is always to generate, as input of the model to be built, a custom dataset according to the supported mobile ML Frameworks. Thanks to the Dataset Generator function, FRITZ AI offers the opportunity, starting from a few sample figures, to automatically generate a dataset consisting of numerous artificial images with elements ready for intelligent segmentation. In the case study in particular, about twenty sample images taken from the laser scanner survey and deduced from photorealistic renderings carried out specifically by external applications were used. Approximately 500 images were returned, starting from 20 input images, which were then used, in order to configure a ML/Tensorflow Core Model, in the AI training based on the recognition of the Corinthian capital (applying the Object Reconition Model by means of the input of various images of capitals acquired photographically inside the church) and subsequently on the specific

Fig. 4. Digital reconfiguration of the spaces inside the church in the current configuration (left) and in the historical configuration (right). In the middle a period photo from the end of the 19th century. The digital model through AI will be more easily superimposed on the real space in AR exploration modes.

recognition of some key pixels to carry out tracking in the AR environment (applying the Pose Estimation algorithmic Model). In this way it was possible to generate a self–compiled Open Source code that could be subsequently used in the Android framework architectures, in the development of the App currently under completion. The Vuforia system compatible code, thanks to which it is possible to use many of the most common AR functionalities, will allow us in a future phase to link the virtual model to some elements of the frame, in our case decorative elements of extreme recognisability and repetition such as the baroque capitals of the pilasters. The structure will therefore support, especially in the wide framing, where there are more points–target capitals, a solid base to support a stable visualization. As mentioned, it will also be possible to attribute to the elements framed by the cam additional contents, historical data, photo galleries, further model–elements that can be manipulated in 3D. These tools essentially offer the possibility of reducing production times by increasing the quality and consequently the interactivity with the user, a ploy that in short supports engagement policies for the participation of Cultural Heritage.

Conclusion

Following the digital survey phase, we reconstructed three–dimensionally the interior of the church hall and the exterior, with particular attention to the reconstruction of the pre–conciliar configuration. The following workflow was dedicated to the development of the AR device, able to visualize in a natural way the previous configuration of the church. This device will be used to allow the fruition of the architectural and artistic value of the church, in the most significant configuration of which there is evidence, with the aim of preserving the aesthetic and architectural qualities of the artefact and to spread greater awareness among the public of the values that the local heritage has expressed, also in view of the lack of protection. The awareness–raising programme will include an online communication campaign and activities with local schools, to foster interest in visiting and learning about the heritage.

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Authors
Alessandro Luigini, Faculty of Education, Free University of Bozen, alessandro.luigini@unibz.it
Stefano Brusaporci, Dept. of Civil, Construction–Architectural and Environmental Engineering, University of L'Aquila, stefano.brusaporci@univaq.it
Alessandro Basso, Faculty of Education, Free University of Bozen, alessandro.basso@unibz.it
Pamela Maiezza, Faculty of Education, Free University of Bozen, pamela.maiezza@univaq.it

 Isbn 9788835125280

Phygitalarcheology for the Phlegraean Fields

Alessandra Pagliano
Greta Attademo
Anna Lisa Pecora

Abstract

The research investigates the theme of the valorization of the huge, but widespread, archaeological heritage of the Phlegraean Fields which, already weakened in its conservation and fruition by the bradyseismic phenomena of the area, is made even more fragile by the absence of narrative strategies, making even local communities unable to perceive its value. The study proposes a systematization of the knowledge of the Phlegraean Fields Park, through surveys and 3D models, integrated by the use of different digital technologies, which together promote effective forms of communication between users and heritage. Each site becomes the node of a network of thematic routes, traced starting from the major attractions of the area and aimed at defining a hybrid landscape, made of in site visits and immersive digital experiences. The goal is to generate a new model of inclusive museum, configuring cultural relationships between physically distant places, between lost spaces and real ruins.

Keywords
infoscape, ICT, AR, VR, archaeology, Phlegraean Fields.

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Introduction

The unique landscape of the Phlegraean Fields, as a palimpsest rewritten over the centuries by complex phenomena of volcanic nature, boasted in the years of the Grand Tour an undisputed fame among European travelers. They recounted in numerous paintings and engravings the wonder and fascination of the ancient classical ruins of the Roman era immersed in a suggestive natural context. Since the 20th century, however, the link between nature and archaeological evidence has been abruptly altered by the unplanned expansion of the modern city, dominated by an uncontested and widespread building abuse. The close, and sometimes inseparable, connection between archaeological sites and modern construction [Di Liello 2005] has strongly influenced the methods of preservation and enhancement of the Greek–Roman remains. The Phlegraean Fields Archaeological Park, in fact, is a fragmented complex, consisting of twenty–five archaeological sites located even several kilometers apart. The Park has many problems, including the state of abandonment of large parts of the heritage, the lack of services, access and transport networks, as well as the inadequate participation of private individuals in the cycle of conservation, enhancement and management of cultural heritage. The impossibility of expropriating private buildings, moreover, does not allow the highlighting of archaeological assets, often even hidden by private individuals themselves. These critical points do not allow to enhance the heritage according to the most modern and shared strategies of conservation and musealization, nor to consistently organize the system of services for accessibility and presentation of architectural findings to the public. The aim of reconnecting the Phlegraean archaeological heritage encourages the search for a new communication strategy capable of integrating all the sites in the identity of a single large widespread park that, overcoming the physical fragmentation of today's urban fabric, can recompose the original and unitary territorial system of the Roman period.

The Phigital Archeology Project

The aim of returning the areas affected by the archaeological excavations to the life of the contemporary city, giving dignity and value to the ancient remains, has guided the research towards the use of appropriate digital communication technologies. These technologies not only allow to replace the physical visit where impractical for structural or security problems, but also to build new forms of relationship between citizens and the ancient urban fabric. ICT and digital networks increase, in fact, our ability to access information and, therefore, knowledge. The design of an integrated exhibition, partly physical and partly digital, made of real movements and virtual paths, physical spaces implemented and digital immersions, also allows to overcome the fragmentation of the Phlegraean archaeological heritage, creating new, more active and emotional ways of narration and fruition. The first step was the construction of a transversal corridor between places because "When we experience territories, we create stories. We model these stories using mental maps" [Iaconesi, Persico 2017, p. 277]. The creation of thematic maps, explorable and questionable, and narrative paths allows to connect archaeological sites even very different and distant, but linked by a common identity matrix. It involves placing certain sites in a thematic transect [Diedric, Lee, Braae 2014], which creates connections even where they are no longer visible. The routes of visit and knowledge, organized according to the original use of the sites and included in a special interactive map in Google Mymaps, are: Theaters, Amphitheaters and Stadiums; Water Sites; Temples; Burial Sites (fig. 1). Each path, involving a large site attractor, could characterize the monthly tourist offer of the Park: in this way the minor sites could benefit from a flow of visitors not easily recallable, thus justifying the costs of the opening of some, otherwise visitable only on request. A process of digitization of the built heritage was then started, through a scientific collaboration agreement with the Park, using photogrammetric Structure–from–motion (SfM) survey techniques, which could return 3D mesh models with high definition textures. These models allow to reconstruct digitally a faithful hypothesis of the original configuration of the good, which becomes a tool of great effectiveness for the communication of the ancient value of the monument. Despite the presence of numerous historical and architectural studies, in fact, the understanding of the archaeological vestiges continues to be difficult for the general public: the loss of the major volumes, coatings and colors, compromises the possibility of appreciating the heritage. The digital reconstruction of the original state, as well as the relocation of sculptural decorations lost or removed for protection needs, would allow the people of the Phlegraean municipalities, first of all, to suggestively enrich the emotional impact in situ, ensuring not only a deeper and more conscious path of knowledge, but also the definition of new relationships between the contemporary city and the ancient urban fabric. The digital models, moreover, constitute the indispensable basis for the technological tools with which we want to implement the narrative. The contextual use of augmented and virtual reality has been added to the more basic use of QR–Codes to link via web to multimedia content. The project also includes the physical installation of descriptive and graphic panels, which are intended to develop a new form of direct interaction between users and heritage.

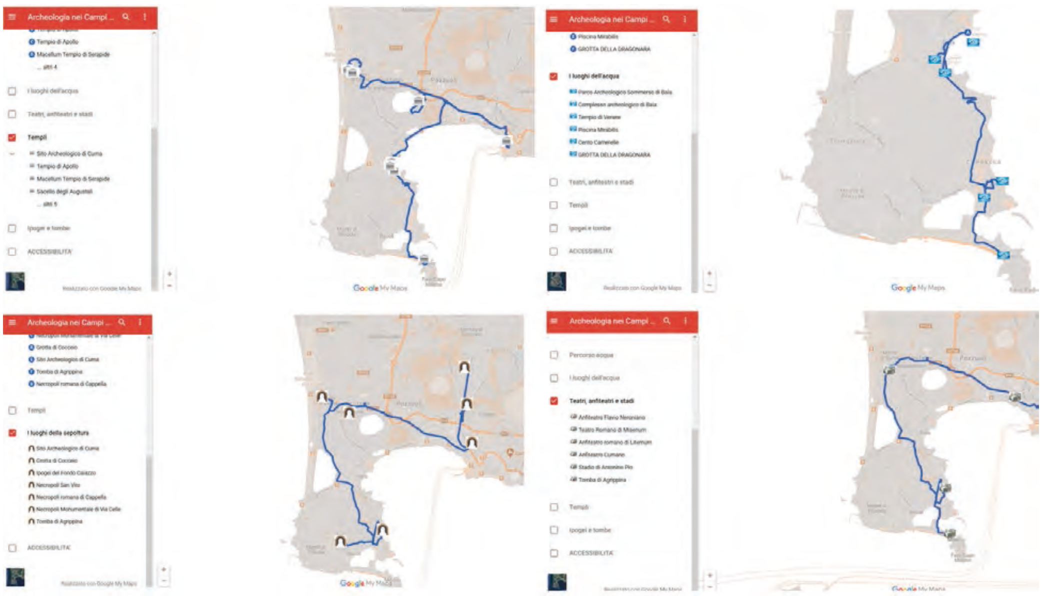

Fig. 1. The four thematic routes for the Archaeological Park of Phlegraean Fields: Temples; Water places; Burial places; Theaters, amphitheaters and stadiums.

Analogical and Digital Augmented Reality

Augmented Reality is one of the choosen strategies, put in practice thanks to the open source app Augment since it allows you to overlay a new layer on archeological remains, the one of digital reconstruction of the structure. A 3D model of the real architecture is shaped through a philologically reconstruction, based on the literary sources and on similarities of coeval and affine buildings. Through the correct detection of an insertion point into the 3D model, the digital content becomes automatically visible in the camera while looking at a marker, that is associated with the 3D model's link while designing. This allows to project, in the same frame, the reconstruction of monument directly onto the archeological remains, completing them if necessary because they are incomplete, absent or unrecognizable due to the time. For example, the "*Sepolcro di Agrippina*", so called because of a wrong denomination during the XVI century, shows the ruins of an ancient theatre of *Giulio–Claudia* period. The loss of the top floor, cavea and stage that were the most characterizing elements of the typical theatral roman architecture, changes the original shape making it unrecognizable: the chance of exploring interactively the morphology and the spaces of a three dimensional model, created on an affordable reconstructing hypothesis, becomes a successful way to communicate even without specialized spectators, with difficulties in spatial imagination (fig. 2). This way, the user can experience the aspect ratio of the architecture reconstructed in its original shapes compared to his physical position, changing the framing with the only obligation of sighting the marker printed on the panel. This way we provide a hybrid and multimodal experience where, the personal perception, physical and essential, of the visit to the archeological site, becomes an interactive tour. So the knowledge process is supported and implemented by the experience through information, spaces and digital objects integrated, in a mixed reality, to real ones. The design has a conceptual graphic style, with a simple monochromatic texture, that associates to the digital model the meaning of "drawing of real". Such choice allows the visitor being aware he's looking a likely reconstruction that doesn't excludes the further configurations as well as he can differ from the excessive hyperrealism of some augmented experiences that, aiming to sensationalism, make the observer a passive viewer rather than a visitor. In these case the archeological approach is drawn and influenced by technology [Volpe 2013]. The same goal is provided also thought the set–up of transparent panels that offer, for each archeological site, one or more perspective images, properly taken from the three dimensional reconstructed environment, reproducing the direct view that the observer would have of the archeological building in a particular position of the expositive path. The finding of the correct relation between archeological fragment and digital reconstruction is given to the visitor, that reassembles the view by overlaying three "red spots", existing in the drawing on the transparent panel, to the three corresponding markers applied on the equivalent points of the real physical structure. In this case we can talk of "analogical augmented reality" because this strategy is characterized by a real space augmented with new signs and high interactivity actively and emotionally involving the visitor to recognizing the lost parts related to the real ruins. The augmented reality, both analogical and digital, gives the chance to overcome the dichotomy between the physical and digital space (fig. 3). However, when some spaces are not accessible any more, it has been integrated with virtual reality experiences, ensuring the sensation of a physical experience inside buildings now impenetrable.

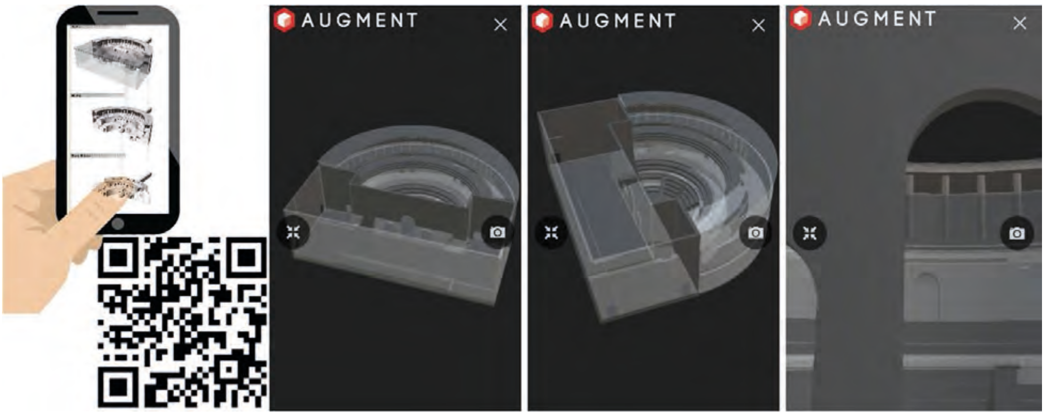

Fig. 2. Digital model of the 'Sepolcro di Agrippina' inserted in the Augment app for Augmented Reality (frame the marker with the scan of the app and the 3d model will appear as in the photo).

Fig. 3. Example of analogical augmented reality.

Conclusions

The proposed "Phygitalarcheology" project is an integrated set–up, partially physical and partially digital that allow to provide new kind of enjoyment, hybrid and multimodal, of archeological sites, ensuring new spatial relations among sites physically far each other, among lost spaces and real ruins, real and digital spaces. This integrated process generates a new model of museum, more inclusive, where digital information is not referred and attached only to the single object or site, but recombine, remix and recontextualize themselves creating always new physical and semantic geographies. The direct and fundamental experience of visiting the site, implemented by digital contents, becomes therefore a narrative–interactive path, encouraging not only the reconnection of the heritage diffused on the Phlegrean area, but even a new sense of knowledge of its value that would reconnect the citizens to their archeological heritage.

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Authors
Alessandra Pagliano, Dept. of Architecture, University of Naples Federico II, alessandra.pagliano@unina.it
Greta Attademo, Dept. of Architecture, University of Naples Federico II, greta.attademo@unina.it
Anna Lisa Pecora, Dept. of Architecture, University of Naples Federico II, annalisa.pecora@unina.it

 Isbn 9788835125280

A Technique to Measure the Spatial Quality of Slow Routes in Fragile Territories Using Image Segmentation

Andrea Rolando
Domenico D'Uva
Alessandro Scandiffio

Abstract

The current research aims at investigating the potential of image segmentation (IS) technology, based on web application, for measuring the spatial quality of slow routes. The big amount of street–level images, publicly available through several applications such as Mapillary, Google Street View, are relevant sources of information, that allow virtual explorations of many places around the world. The (IS) technology allows partitioning of a single digital image into sets of pixels in order to read and recognize the visual content within the frame of the image. By applying IS technology to the images taken along a defined route, it has established a method for grouping images in relation to their spatial features. The method has been applied to some stretches of slow–mobility routes, that are localized along the fragile coastal landscape of Trabucchi, south of Italy. A selection of images along the route, both in the outdoor and urban space, has been analyzed, with the aim to test the effectiveness of the method, able to produce useful information to define a Spatial Quality Index.

Keywords
slow routes, mapping, spatial quality, image segmentation, fragile territories.

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Introduction

The methodology presented in this paper results from a search for a solution to the problem of assessing the spatial quality of slow mobility routes [Scandiffio 2019; Bianchi et al. 2020], that are located off the beaten tracks, crossing territories that are marginal and distant from densely populated areas. The majority of studies on the subject refer to major urban centers, neglecting fragile areas of the territory. These areas are often characterized by a structural lack of data, which makes in–depth analysis difficult. However, it is possible to perform advanced research methods in the field of spatial analysis, by exploiting the potential of street–level imagery, users' generated contents that are available on the web portals. These methods belong to the Artificial Intelligence (AI) family. It is beyond the scope of this work to make a detailed analysis because, within this particular type of software, there are many subsets, each of which has a specific function [Zhang et al. 2018; Zhang et al. 2019; Cao et al. 2018]. The current research refers to a particular system of Machine Learning, named Deep Learning, that is based on Neural Networks [Buratti et al. 2020]. This particular subsystem allows analysing imagery and recognizing elements already present in an internal database of the machine. The use of an AI system is necessary because the database does not contain precisely the identified element, but only a series of similar elements that are analyzed and compared until an ideal candidate for the final recognition is found. The system, therefore, learns from the elements supplied to it and increases its knowledge step by step. Once the element has been recognized in the image, an even more specific procedure is used, called Image Segmentation (IS), which perimeters the object providing its position and area. Thus, this digital ecosystem returns the position and quantification of an element within a single image, which corresponds to a geo–referenced coordinate of the landscape. By performing the IS method to a sequence of geo–referenced imagery, it is possible to capture the landscape features along the route , which can be used for measuring its spatial quality. It is important to underline that the interpretation and assessment of the quality cannot be fully automated in the first instance: correct reading and interpretation of images must be prepared, defined and progressively tuned through an iterative process of machine training, possibly implemented and improved by massive users contributions. The process is in fact based on comparative assessments and still requires, in any case, a direct experience of places.

Case Study

The case study to which the methodology was applied is the Costa dei Trabucchi greenway in Abruzzo Region; a greenway converted into a tourist cycle route since 2017 [Marcarini, Rovelli 2018]. This route will stretch, upon completion, for 40 kilometers between Ortona and San Salvo. At the time of writing this work, it is almost wholly completed in two sections; the first to the north between Ortona and Fossacesia and the second to the south between Casalbordino and San Salvo. The northern section of this route was primarily constructed by the Adriatic railway line's retreat, leaving a void along the coast. It is currently almost completed and is accessible except for the tunnels, which are still under renovation. The southernmost section is a route that stitches together different territorial environments, the coastal towns of Casalbordino, Vasto, San Salvo, and the Regional Nature Reserve of Punta Aderci. This section has been entirely completed, except for the completely inaccessible tunnels. The coastline landscape along the route is very scenic, with wide and sandy beaches that alternate to natural cliffs that are interrupted by small urban settlements. Both sections are located protected natural areas of great value such as the Reserve of the Butterfly Cave and the Lecceta di Torino di Sangro and Trabucchi in San Vito, Fossacesia, and Vasto. For the purposes of the study, shots were selected in 6 sections belonging to the two sections. Often, the elements, that are in–between the cycle path and the sea, such as vegetation and houses, impede the landscape's unobstructed view, sometimes trapping the route in canyons in which the perception of the valuable elements of the landscape is seriously compromised.

Methodology

The current methodology starts from the imagery surveying of the route, which has allowed to record the GPS track and to take photographs, orthogonal to the route direction, every 10 meters, by using the web application Mapillary [Porziy et al. 2020]. It is a web platform that automates mapping tools, by collecting street–level imagery taken by users with a standard smartphone. Mapillary exploits computer vision tools [Warburgy et al. 2020] and it allows the recognition system's application. The methodology is based on the object detection in images, based on IS technology. This technology is part of the digital ecosystem of Machine Learning that allows the recognition of the perimeter of objects and their measurements within the whole image. The objects are assimilated to the elements included in a training model already existing in the Machine Learning engine, and a percentage of occupation of the framed field of view is provided. An ad hoc algorithm has been written in Python language with the aim of extracting quantitative data related to each image. This algorithm makes it possible to shift the IS' heavy computational burden from local machines to remote cloud systems that operate the recognition in a much more efficient way. The image elements are extracted in the form of very rich JSON archives because they include the type of object, the area occupied in the image by each object, the recognition reliability percentage, and the coordinates of all the points that define the perimeter of the object. The algorithm skims all objects that occupy an area of less than 5% of the entire field of view, returning only the family and sub–family to which the object belongs, and the area occupied.

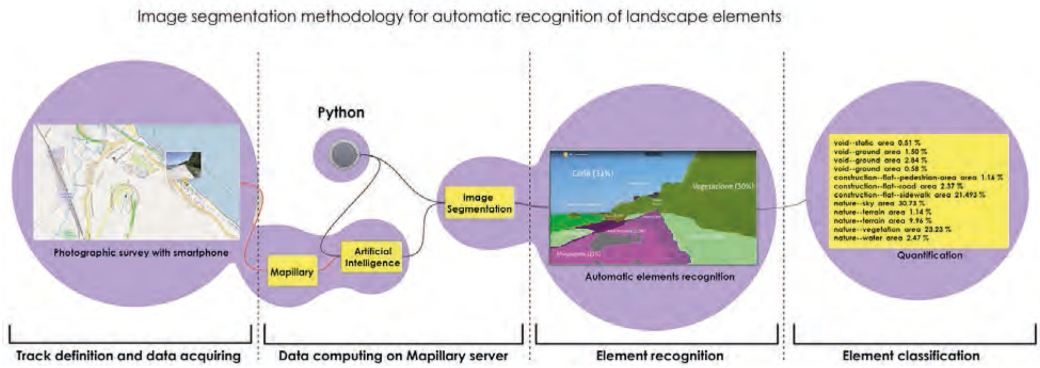

Fig. 1. Workflow of the Image segmentation methodolgy for automatic recognition of landscape elements

The grouping of images has been done by considering three main layouts as reference for the scenes. The layouts have been drawn, by selecting the horizontal surface of the path, the vertical obstructions and the openness of the sky. By assuming the horizontal surface of the path as an invariant component of all images, different thresholds of the area percentage of each component of the scene have been applied, in order to analyze the surfaces in the surrounding of the path, which, effectively, affect the landscape perception. Three different scene–types have been defined for grouping images. The scene–type 1 corresponds to an open environment, with small vertical elements on the sides and on the background of the image. The scene–type 2 corresponds to an environment where a wider surface of vertical elements is present only on one side. The scene–type 3 corresponds to a closer environment, surrounded by vertical elements on both sides. For each scene–type two different images, belonging to the outdoor and to the urban environment, have been selected, in order to test the effectiveness of the method. Both images of each scene–type have been selected in the same range of area percentage values (fig. 3). For each image it has been extracted the area percentage of each object in the image, through the Python algorithm. The raw values of area percentage, derived from the IS, have been grouped into eight main categories (path, sky, vegetation, edgings, water, terrain, buildings, mobile objects), in order to simplify the categorization and allow an immediate reading. For each category, it has been computed the area percentage.

Outcomes

By processing the images with IS, three different thresholds have been identified for assessing the spatial quality of the landscape crossed by the route. The threshold values of the sky and vertical elements (vegetation, buildings, edgings) seem to be the most interesting indicators to outline the features of the scene.
The images in the scene–type 1 have the area percentage of the sky more than 40%, and the sum of the area percentage of vertical surfaces (edgings, buildings, vegetation and mobile objects: people and cars) is less than 30%. The images in the scene–type 2, the area percentage of the sky less than 40%, and the sum of the area percentage of vertical surfaces is among 30% and 40%. The images in scene–type n. 3 have the area percentage of the sky less than 20%, while the sum of the area percentage of vertical surfaces is more than 40%. The thresholds values identified in this research, could be modified and adapted, if they are tested in other environmental contexts.

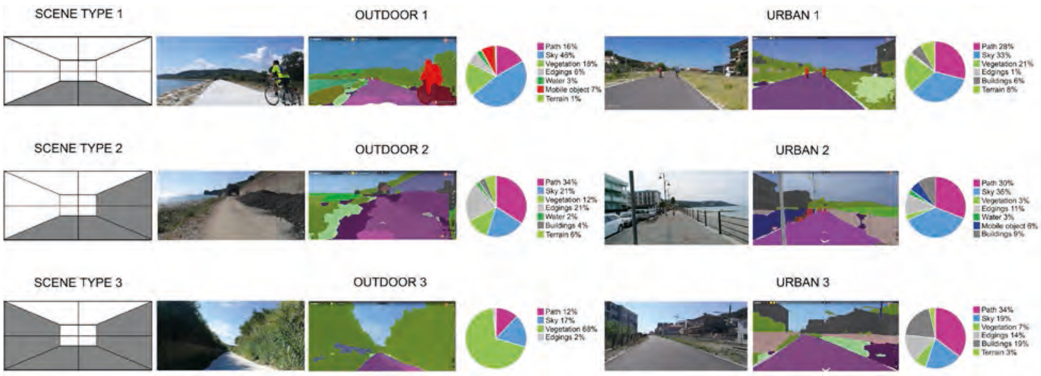

Fig. 2. Comparative table of landscape features along the "via verde della Costa dei Trabucchi" greenway.

Conclusion and Future Research Developments

The limits of this methodology are twofold. The first is related to the system's problems, the second to the limitations of images data provision. The Mapillary system only allows the recognition of elements that can be read by referring to a database which is pre–defined by its developers and not open to changes. Therefore, some elements typical of the area covered by the case study are not taken into account. For example, the trabucchi, amphibious machines that are the main heritage – from which the coast itself takes its name – are selected as Void objects, not recognized. These objects along with other notable features, are not recognized because the Mapillary database only includes standard features. It would be necessary to customize the database to select only those objects that are expected to be retrieved according to their relevance for our specific qualitative analysis. Such an update of the tool could take advantage of the peculiar characteristic of Machine Learning systems, namely the ability to learn through analysis, and improve its precision and reliability. However, the problem arises when training this new database, whose operation requires significant machine time resources and the need to rely on external structures to complete the process. During the analysis of the case studio, problems were encountered in the recognition system because only 100 items per image are analyzed at any one time. The main features could be included in this value, but some attempts at element recognition only found 51% of them. This limitation can be overcome by directing the system to search for single categories of objects, instead of the totality, by expanding the number of detectable elements. To overcome this first type of limitations, the evolution of methodology will consist of updating the Python algorithm of parameter extraction, e.g., implementing the grouping of the elements recognized in the indicated categories. This procedure would start from the sum of the elements with equal features to automatically group and draw a graph of what is currently done manually.
The second type of limitation concerns how photographs are taken. A positive aspect of Mapillary is the possibility to survey using a standard smartphone. This flexibility implies a significant problem for recognition: namely the angle between the direction (perpendicular, along the lens axis to the smartphone sensor) and the horizon. Tilting the field of view downwards increases the amount of land (increasing the number of elements included and incurring in the problem told above) in

the frame. Tilting it in the opposite direction increases the percentage of the sky that fills the frame. The incidence of this factor will be the subject of future research developments. A further limitation of this type is the standardization of the photos because they are taken with various instruments with different resolutions and fields of view, with intuitively different results. The differences induced by these limitations can be overcome by using standardized tools for capturing photos, implementing a camera whose inclination, position, and shock–absorber can be controlled within specific well–defined parameters. A completely different approach to this issue is relying on more reliable photo databases such as Google Street View [Zhanga et al. 2020; Anguelov et al. 2020] but with limited coverage of the slow mobility routes covered in this work. A better definition of the thresholds for each category can be found, in order to apply the method to other territorial contexts. Related to this problem is the limited portion of the space that is framed by the images. In fact, this method only allows to detect the landscape elements that are framed in the images. The application of other methods that define landscape components extracting them from GIS database could be integrated in the procedure. The best foreseen solution could aim to define the most relevant components of a landscape extracting and defining them both from GIS databases (made of geometric entities derived from visual knowledge) and from Image Segmentation procedures, that feed a similar database, but using visual recognition of the same entities. In the end this double checked definition of entities should assure the correct definition of each item. Further developments could investigate the possibility to define a set of relevant objects referred to geometric entities (points, lines, surfaces) to be considered as common database records, so to be recognized and confronted both in the image segmentation based process and in its complementar GIS based method of analysis.

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Authors
Andrea Rolando, Dept.of Architecture and Urban Studies, Politecnico di Milano, andrea.rolando@polimi.it
Domenico D'Uva, Dept. of Architecture and Urban Studies, Politecnico di Milano, domenico.duva@polimi.it
Alessandro Scandiffio, Dept. of Architecture and Urban Studies, Politecnico di Milano, alessandro.scandiffio@polimi.it

 Isbn 9788835125280

When the Real Really Means: VR and AR Experiences in Real Environments

Giorgio Verdiani
Ylenia Ricci
Andrea Pasquali
Stéphane Giraudeau

Abstract

During this past year the Laboratory for eXtended Realities (DIDA–LXR) from the DIDALABS system at the Department of Architecture at the University of Florence, has experienced a various number of activities. Most of them linked together digital modelling of no longer existing architectures and still in place Built Heritage. Others were aimed to develop an "Augmented Virtual Reality" using specific environments/locations (for example a boat) to enhance the sensations of the user during the experience. Some others were based on direct VR shooting, using advanced panoramic cameras and creating a point of view compliant with the specific impressions that the place should transmit.
In the contribution proposed here the AR, VR and XR experiences from this personal research will be presented sharing the specific subjects, the evaluation of usable technologies, the strategy for shooting, survey, processing and post–processing, the dissemination of ideas and the lesson learnt.

Keywords
virtual reality, augmented reality, photogrammetry, aerialphotogrammetry.

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Introduction

The new possibilities created by the Laboratory for eXtended Reality were immediately followed up with case studies applied to cultural heritage. We consider the possibility given by virtual environments and augmented reality a great potential for reading and study, the way to increase and facilitate the knowledge of the architectural heritage.
This technological development has led us to the need to deepen the existing possibilities of recording or surveying the existing. The growth of this knowledge has allowed us to think about topics that have a key theme and to experiment with new possibilities of fruition and use of the collected data. The whole set of experiences was oriented to Mediterranean subjects connecting the eastern and western parts of the "Mare Nostrum". In this way, the Medusa's Heads passing from Constantinople to Istanbul, the Tetrarchs' Statue in Venice, the Venetian Lagoon and its story, becomes the first series of fragments of a VR and AR plot around the Mediterranean Sea. The approach is to create a versatile set of multimedia elements, oriented to work in a "classic" environment like the traditional display as well as in modern solutions like the immersive visors. At the same time, while experimenting with different solutions and subjects, specific attention was given to the users' experience, gathering information and suggestions from the people using the virtual/augmented environments. This was quite useful in addressing and enhancing the further developments of models and proposals. The guidelines followed in all the testings and experiments were aimed at the production of very persuasive environments enriched by fascinating and valuable contents.

From Site to Virtualization

The paper presents experiences of eXtended Reality that aim to increase the user's sensory perception. This evolution is not sought by artificial technological inputs but by the real environment. Analyzing and structuring the real physical location where to place the device for the use of the digital environment we aim to add real inputs to complete the virtual experience. From this, the cases presented are strongly different and distinguishable but with a common theme. The research wants to focus on the need to link the place of the fruition of the virtual environment with the digital product. This is to have a more complete product. However, do not want to take away the importance of the greatest potential of Virtual Reality, that of relating to the object of study in an environment completely parallel and independent from physical reality, releasing the digital object from the real world. The reasoning wants to underline how eXtended Reality is not only the trivial union of AR and VR but it finds complete fulfilment in the knowledge and in the dialogue with the environment in which the experience takes place. Not only structuring and engaging with the location but also welcoming (and possibly shielding) the stimuli and features that are part of it.

Case Study One: the Theater of the World by Aldo Rossi

The first step in our journey to rediscover the Mediterranean Sea is Aldo Rossi's Theatre of the World [Brusatin & Prandi, 1982]. This iconic temporary architecture was built between the late seventies and early eighties and it has represented the symbol of what is known as temporary installations. Created specifically for the Venice Biennale of Architecture in 1979 [Garcìa 2006] still recalls more than 30 years later, the typical charm of something that was once there and now no longer exists, if not virtually. The purpose in this research is to keep this feeling of curiosity alive and untouched and then fulfil it, thanks to the development of a virtual environment, in which it has been relocated the Theater.
The process behind the virtualization began with the documentation about the architecture and it was necessary to collect information about the structure and the form of the building itself, using architectural drawings and various photographic sources. Thereafter it was possible to carry out the digital modelling of the object, performed with Maxon Cinema 4D and then exported in Unreal Engine for the virtualization of the environment. The experience led to the digital rebirth of this disappeared architecture (fig.1).

The virtual tour was also designed as a place of education for students, including information points making the experience active. Following the example of the Biennale, it was decided to set up a temporary installation on a boat to create the dialogue with the real environment using the external inputs given by the location itself, and in this case, the movement of the boat and the sound of the water.
Part of our research is also focused on another type of reality that allows us to create an overlay of the reality we find ourselves within. The model was reshaped and re–textured and the process was carried out specifically to obtain a digital model suitable for augmented reality and dedicated software developing a beta version of an application for IOS devices using ARKit. The aim was to showcase the effectiveness of Augmented Reality technology as a powerful tool that can be successfully applied to the research process and the communication of the Cultural Heritage.

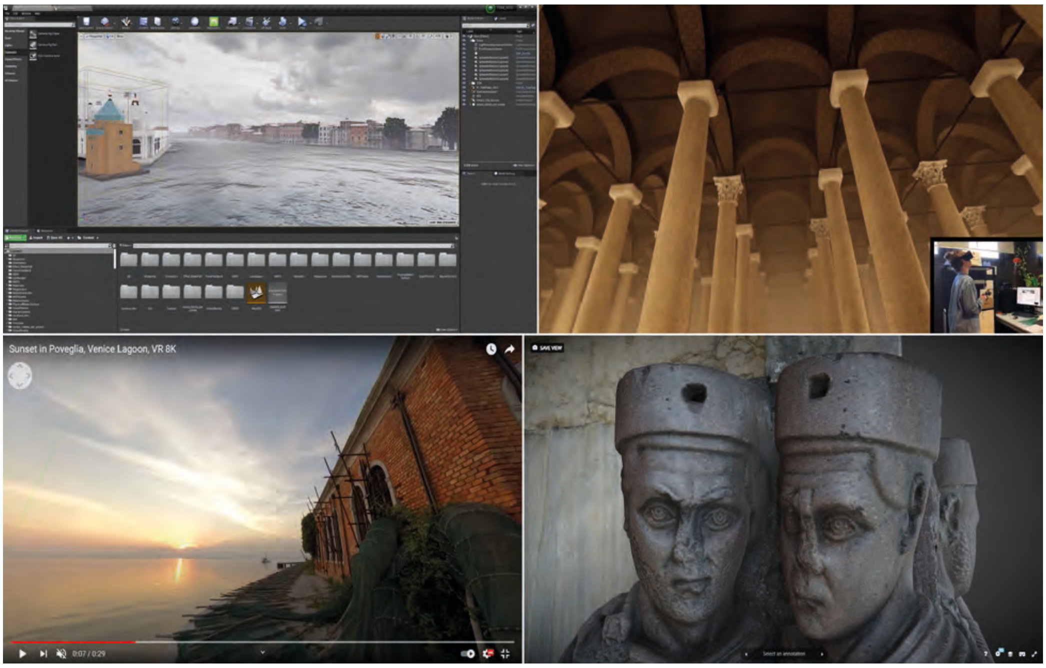

Fig. 1. The theater of the World reconstructed in its virtual space using Epic Games Unreal software, view of the virtual tour in the Basilica Cistern; view from a Panoramic VR shot taken in Poveglia; detail of the Tetrarchs statue in Venice from the sketchfab.com platform.

Case Study Two: The Medusa Protomes Inside the Basilica Cistern

It is safe to say that to know better Venice it is essential to know Constantinople. The two cities were strongly linked by commerce, art exchange and share some robust environmental aspects. The Basilica Cistern, in Turkish *Yerebatan Sarnici*, is one of the largest ancient sites below the ground of Istanbul, built by the Emperors to satisfy residents' water needs. Inside the building, under two of the 336 columns, we can find the Medusa Protomes, elements of interest not only for their history but also for the mystery about their origin [Verdiani et al. 2019]. The reconstruction of the Basilica Cistern was based on existing surveys, creating a digital model, optimally proportioned and that responds to the real [Ricci et al. 2018]. The Unreal Engine software was used to rebuild the Cistern in a virtual environment and to offer a format that can be reused in any museum context. Inside the tour the users have access to a series of multimedia containing information about the site, about the myth that lies behind the medusa protomes and the recontextualization hypothesis proposed. This is the exact demonstration of the quality of this kind of result, which is an active type of communication that offers the simulation of a real environment and an unforgettable experience enhanced in this case by the utilization of some recorded sounds captured inside the Cistern during the survey. A short video about the virtual tour in the Basilic Cistern in Istanbul can be seen in Youtube at the following link: *https://youtu.be/LsrxRaDrAo0*.

Case Study Three: Venice the Tetrarchs Statue

The Tetrarchs statue in St. Marco Square, Venice, is a clear sample about reuse of spolia as a demonstration of continuity and tells a yet partially mysterious story of artworks moving around the Mediterranean during strong and dramatic historical events [Dorigo 2014]. Such an element, stable and solid across the centuries, but at the same time capable of a long and adventurous journey in its past [Missagia 2015], rich in references and symbols, apparently capable of hiding some intriguing stories and worth to be admired in its details [Rees 1993], was found ideal for mixing two different modern digital approaches. A VR 360 short movie, recorded in timelapse mode was taken just in front of the statue, in a quite crowded hour, in the moment when the light of the sun is moving and the shadows are going to cover the corner. This short video clip was built to enhance the perception of the place with the special relationship between the static pose of the Tetrarchs and the fluid movement of tourists and workers all around the square, with the option of having a fully dynamic 360° point of view. The shooting was operated using an Insta360 Pro II camera, capable of taking 8K resolution movies and stitching them in real–time.
The video can be seen on youtube in the DIDA–LXR channel at:
https://youtu.be/xqvE1HuiqJc.
To satisfy the need of details and allow a complete exploration of the sculpture, photogrammetry was operated using a Nikon D800e. The full set of shots was then processed using Reality Capture software and producing a fully textured model of about 500 million triangles, later simplified to five million and loaded with high resolution texturing on the Sketchfab.com platform and visible at *https://skfb.ly/6UZ8P*.
These two digital products connected each other using simple links, allow a double and quite different reading and seeing this special corner in Venice, offering a better understanding of the context and specific details in a way otherwise impossible in place, a valid alternative to the direct visit, but also stimulation and invitation to go in place and complete the knowledge about this migrating stone.

Case Study Four: Poveglia, the Abandoned Island

On the occasion of a recent trip in Venice, it was discovered a particular tiny island located inside the Venetian Lagoon named Poveglia offering the opportunity to test and discover the potential of a new tool, the Insta360 Pro 2 camera on a very fascinating environment where historic elements and urban legends are mixed [Cavallo & Visentin 2020]. After having chosen the right spots from which shot and film, the data was processed and it has been created a 360 tour that gives everyone the chance to visit the island. It has proved to be a very useful tool and methodology for the dissemination of information about the existing heritage.
A series of Panoramic VR videos can be seen in Youtube in the DIDA–LXR Channel, at: *https://youtube.com/playlist?list=PLB5GHBSIDCa-u7-e1CQrAvQ1nEmpKZLKk*
Speaking of useful tools for surveying and photogrammetry, which in recent years have made significant advances in technology and functionality, we can not help but think of drones (UAV – Unmanned aerial vehicle), and the support they give in a survey thanks to their potential and the ability to access a point of view previously unthinkable.
It is possible to recreate a 360 panorama, later navigable, using the flight application of the aircraft. The method is quite simple, taking advantage of the panoramic mode – 360, the drone, autonomously, takes a series of photos in about 40 seconds in order to develop a navigable overview through the drone's piloting APP: FreeFlight 6. A sample of the result obtained from this procedure can be seen in the DIDA–LXR Youtube channel at: *https://youtu.be/cjJz37JYDAU*
For the flights the drone used was a Parrot Anafi. The drone weight was reduced to 300 grams in order to perform non–critical operations also in an urban context, as required by the regulations in force at the time of the flight.

Conclusion

The present paper is composed by a sequence of studies with highly diversified contents. As stated in the initial part of the paper, the relationship with the resulting digital products has been accurately analyzed, trying to increase the virtual experience, creating a direct network between the fascination of the stories, the impression coming from the real places and the option offered by the digital solutions.

The desire of experimenting and the will of building specific and effective results is at the base of a research aimed to find efficient solution for presenting parts of the Built and Cultural Heritage in the way they deserve exploiting their best characteristics, creating a specific digital version that is an enhancement or an alternative to the real but that doesn't ask the user to settle for quality and experience, it simply provide a digital approach offering the digital version of that cultural values. The case of the Theater of the World is totally concepted as a dialogue between the location and the virtual reality, increasing the senses' suggestion. In this sense the statue of the Tetrarchs has opposite features, creating interest in something existing as a rich evidence of interactions in the Mediterranean area, the detailed photogrammetry links the real existing with virtual perceptions of knowledge and (maybe) with a desire of completion and investigation about the mysterious and impossible to be told story of its moving from Costantinople to Venice. The other two themes provide the possibility of new points of analysis, which move away from the theme in the studio but still keep close contact with the stimulus coming from the real, such as the introduction of recorded environmental sounds, in the case of the Protomes of Medusa.

This set of experiences have a value that goes far beyond describing the themes and illustrating technologies and methods. They are traces of the experiences and above all provide "a way" about sharing points, suggestions, fascinations, they try to create a specific link between the inner value of stories and places in the continuous tentative of enriching the digital contents with valuable learning occasions. Not only in the will of "capturing" the users, but in the true belief that "Digital Heritage" is an occasion allowing an easier reading and an option for spreading the knowledge of Cultural Heritage, but it need a correct comprehension of these values which is the first real step in creating a constructive system based on a sort of circular flow of attraction –> exploration –> knowledge –> digitalization –> dissemination –> learning –> spreading –> attraction.

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Authors

Giorgio Verdiani, Dept. of Architecture, University of Florence, giorgio.verdiani@unifi.it
Ylenia Ricci, Dept.of Architecture, University of Florence, ylenia.ricci@unifi.it
Andrea Pasquali, Dept. of Architecture, University of Florence, andrea.pasquali@unifi.it
Stéphane Giraudeau, Dept. of Architecture, University of Florence, stephane.giraudeau@unifi.it

Isbn 9788835125280

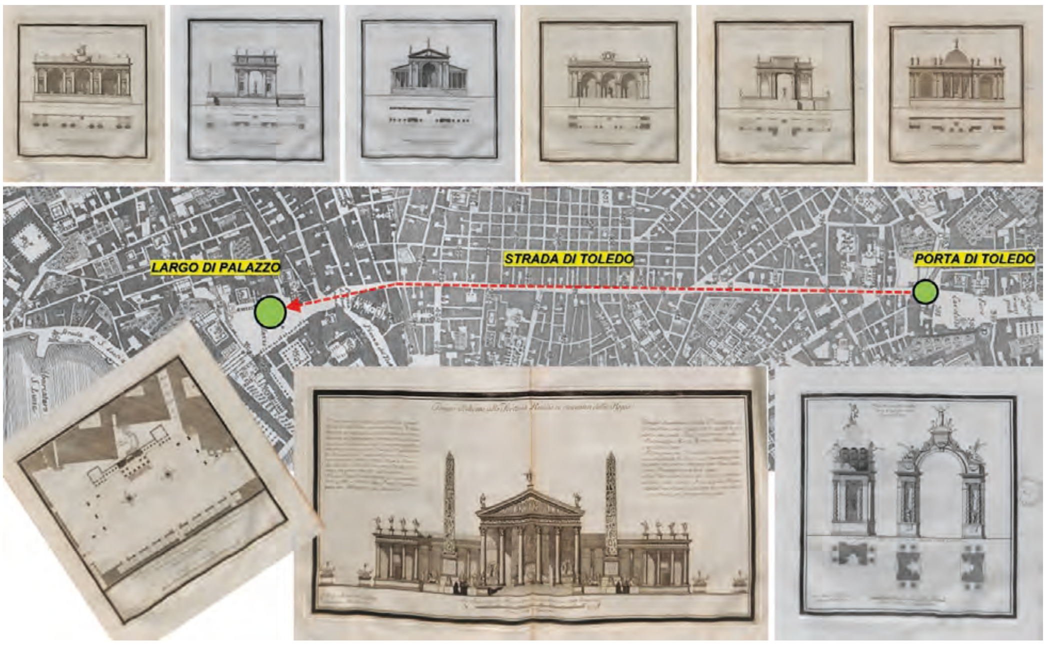
Drawing, Visualization and Augmented Reality of the 1791 Celebration in Naples

Ornella Zerlenga
Vincenzo Cirillo
Massimiliano Masullo
Aniello Pascale
Luigi Maffei

Abstract

This paper investigates the ephemeral architecture of the eighteenth century in Naples through the literary and iconographic sources found in the volume *Idee per le pubbliche feste nel ritorno in Napoli de'nostri Augusti Sovrani dalla Germania […]* by Gaetano Barba (1971). The goal is an unprecedented representation, modeling and fruition project, accompanied by a graphic visualization of the places to better understand the architectural and urban space in the absence of allusive images of three–dimensionality. Subsequently, the visual construction of the contexts on an urban and architectural scale made it possible to disseminate the compositional elements of the celebrations and the internal perceptions to a non–specialist public. Finally, an Augmented–Reality application prototype.

Keywords
ephemeral architecture, celebrations, representation, 3D modeling, augmented reality.



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Through the synergy between the disciplines of Drawing and Technical Physics, this contribution analyzes the methods of graphic representation and the digital modeling of the eighteenth–century celebration designed (and not realized) in 1791 by the architect Gaetano Barba (1730-1806) in Naples and described in the volume entitled: *Idee per le pubbliche Feste nel ritorno in Napoli de' Nostri Augusti Sovrani dalla Germania dell'architetto Gaetano Barba, Accademico di merito di S. Luca, edito a Napoli nel 1791 da Gaetano Raimondi*.
The results achieved with the graphic analysis and the build of new images are intended to represent, thanks to the aid of digital representation methods, both a cultural contextualization of the methods of representation used, and the return of a three–dimensional model to be understood as a phase of a subsequent study aimed at verifying the new technologies of virtual representation at the service of cultural tourism. The goal is to make the design 'augmented' so that the visitor can relive the context of the 18th century Neapolitan celebrations. Therefore, it is proposed as an application case, the virtual reconstruction of the *Porta di ingresso sulla strada di Toledo* and its implementation in an Augmented Reality application. The application conceived for this purpose was created with the support of SENS i–Lab, a human–centered, multi–physical and multi–purpose university laboratory for the creation, development, prototyping and interaction of man with products and physical and virtual systems of the Department of Architecture, Industrial Design of the University of Campania Luigi Vanvitelli [1].

The Drawing of the Ephemeral: the Regulating Principle of the 1971 Celebration in Naples by Gaetano Barba

The ephemeral concept has been (and continues to be) for the city of Naples a constant cultural expression, which is poured out not only in the everyday life of the people but also, and above all, in its architecture. The design of ephemeral architectures (such as fairs, *cuccagne*, pyrotechnic machines) saw widespread use in Naples during the eighteenth century with the creation of installations with a considerable design value [Cirillo 2017, pp. 101-118].
The theme of the 'urban' celebrationl reached one of its most significant moments in the eighteenth century with the staging of ephemeral settings that manifested the greatest affirmation of the culture and Art of that time. Their realization relied on a great variety of technical (architects and engineers), figurative and entertainment skills (musicians, painters, set designers). This synergy highlighted the taste for spectacularity, grandeur, sumptuousness and the decoration of the apparatuses to arouse the effect of wonder [Mancini 1997].
Within this context, in August 1790 in Naples, in the place called *Largo di Palazzo* (the open space in front of the Royal Palace) and along Via Toledo, a cycle of festivities was celebrated in honor of the return of the kings of Naples, Ferdinando and Maria Carolina, who were in Vienna for the wedding of their daughters Maria Teresa and Maria Luisa. To celebrate this return, a competition was held between the best architects of that time. The celebrations' principles were banned and published in the volume entitled *Nel felicissimo ritorno degli Augusti Sovrani Ferdinando IV e Maria Carolina d'Austria. Feste Pubbliche della Fedelissima Città di Napoli (1791)* at *Giuseppe Maria Porcelli Librajo,* e *Stampatore della Reale Accademia Militare*. The aforementioned volume reports as winner the set designer of the San Carlo theater Domenico Chelli, but there is no iconographic documentation about his project. However, Chelli, also with small formal changes, was inspired by the project outlined by the architect Gaetano Barba published in the same year in the volume *Idee per le pubbliche Feste nel ritorno in Napoli [...]* [Mancini 1980, p. 331].
The volume *Idee per le pubbliche Feste nel ritorno in Napoli [...]* by Gaetano Barba accompanies the reader to understanding the events not only through the reading of the short text but above all through the attached images. The images contained within the volume consists in ten engravings of the architectural elements, which set up the celebration. These representations appear ordered according to a spatial sequence which, starting from the *Porta di ingresso sulla strada di Toledo* and through the *Sedili* located along Via Toledo, leads to the rear scene of the *Tempio dedicato alla Fortuna reduce*, set up in *Largo di Palazzo* (opening figure). All the engravings show the architectural organisms represented in plan and/or elevation with full adherence to the neoclassical style [Jacazzi 1995]. The architect offers a general description of all the elements of the celebration and outlines both their appearance and their functions and destinations.

The installation of the entrance door was placed where the Ancient Royal Gate, also known as the *Spirito Santo* (current south side of *Piazza Dante*). Later, the celebrations would continue along Via Toledo, which was to be adorned and decorated with six *Sedili* (seats), called *Ornati Architettonici di rilievo*, which would have had the task of embellishing and making the façades of the street more pleasant.
The six seats suggest that they would have been arranged with the long side parallel to the road axis. In this sense, it is plausible to think that these structures would have leaned on the elevations of the buildings on Via Toledo, both for the lack of a second elevation in the back and for the analogy with other festivals such as, for example, that of Santa Rosalia in Palermo where ephemeral structures were placed on the facades of existing buildings [Isgrò 2019; Di Fede 2005-2006, pp. 49-75]. In *Largo di Palazzo*, a majestic Temple dedicated to *Fortuna Reduce* would have concluded the festive itinerary. The temple with colonnades, a large central staircase, two obelisks, statues and two arms of pedestals surmounted by statues of sirens, would have stretched towards the statue of the Giant and the Church of the Santo Spirito (demolished), thus redesigning the planimetric layout of the square with a regular shape. The drawings by Gaetano Barba allowed a correct and meticulous analysis and representation of all the elements designed, thus succeeding in grasping the dimensional and spatial character of each structure. In this sense, starting from the literal description, from the project drawings and from a conversion into meters of the dimensions indicated in 'Neapolitan palms', through graphic analysis, modeling and subsequent visualization (fig. 1, above) an unpublished image is returned. of the event according to the criteria and ideas of Gaetano Barba respecting the urban context of the Neapolitan eighteenth century (fig. 1, below). Given this, the digital reconstruction of the entrance door and the virtual location in the current Piazza Dante through the AR application constitute the case study for visualizing both the party imagined by the designer and the actualization effect.

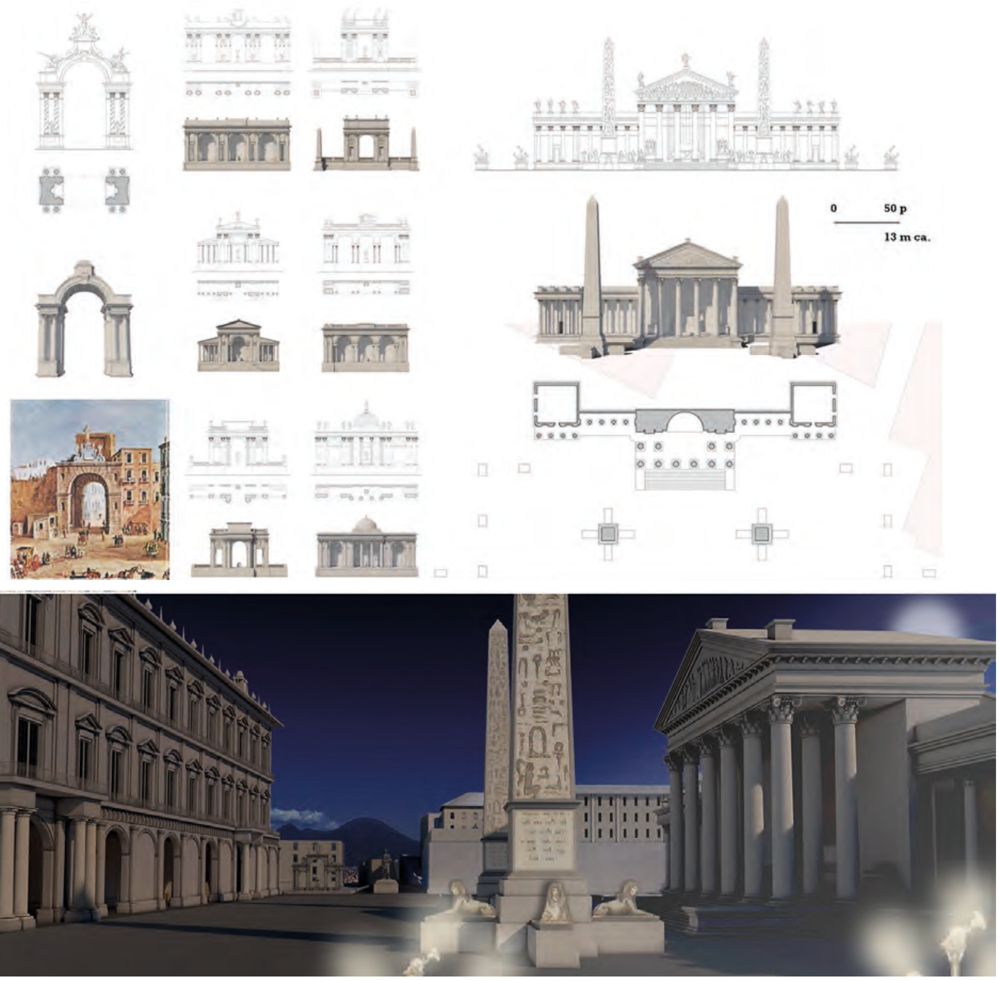

Fig. 1. Above, Entrance Door, Seats and Temple of Fortuna Reduce: plan–altrimetric drawings and 3D modeling; below, visualization of the Temple of Fortuna Reduce in Largo di Palazzo (drawings and graphic elaborations by Pasquale Valentino and Vincenzo Cirillo).

The Prototype of the Application in AR

The development of digital content that can be used through mass–market devices (e.g. mobile phones, tablets) and head–mounted displays in the last decade has found a fertile field of application in the world of Cultural Heritage [Voinea 2018]. More and more varied and interactive digital contents, accompanying the offer to tourists, are having increasingly interesting implications: (1) the possibility of visiting sites that no longer exist or are inaccessible represents an opportunity for museums to expand the offer of contents and cultural sites, with the ability to attract and intrigue even a younger user target; (2) the digital contents are conveyed to the end–user directly, providing them with a more or less immersing experience according to the types of devices in use. (3) The digital contents are made available to the user through their smartphone, with the possibility to contextualize it in its original place. Taking advantage of the opportunities deriving from Digital Cultural Heritage applications, an App prototype has been created. Through the Augmented Reality (AR), the App allows users to walk through the streets of a city, its monuments, artefacts, lost buildings or, in any case, not accessible. The first application concerned the artefact of the entrance door sited in Via Toledo in AR. The workflow sees a first phase dedicated to creating the contents necessary for developing the App: Three–dimensional model, Texture, Sounds. The three–dimensional model was made starting from the drawings recovered in the bibliography, as described above. In this phase, more attention was focused on defining the details of the 3D model: frames, moldings, capitals, rather than on the materials. It was important to create a reasonably light model in terms of 'vertex counting' which, however, did not compromise the elements' definition. The complete model in all parts was then exported to the 3DsMax software for polygon optimization and asset preparation. In particular, the elements that make up the product have been appropriately divided, and IDs have been assigned for the diversification of materials. The textures were downloaded from Megascans libraries. As for creating sounds, a sound effects composition operation was carried out, starting from professional libraries' sounds. Anthropogenic sounds such as pedestrian footsteps, people's voices, and music have been downloaded to recreate the party's typical sound setting. The sounds have been converted all mono and imported into the development environment. Here they have been inserted as points sound–source so that you can make a spatialization of the sound. The App was created within the 'Unreal Engine 4' development environment. The *ARCore* framework, necessary for the recognition functions of surface planes in AR mode, was implemented here. A basic interface has been inserted that allows the user to enable the camera and frame the horizontal plane where the 3D model will be displayed. The actor was then created to be placed on the surface, with the artefact's 3D model inside. Once the floors are recognized, a tap on the screen allows you to position the object; subsequent finger gestures will enable you to move and rotate it (fig. 2). A first test was carried out directly on site. In piazza Dante, near the beginning of

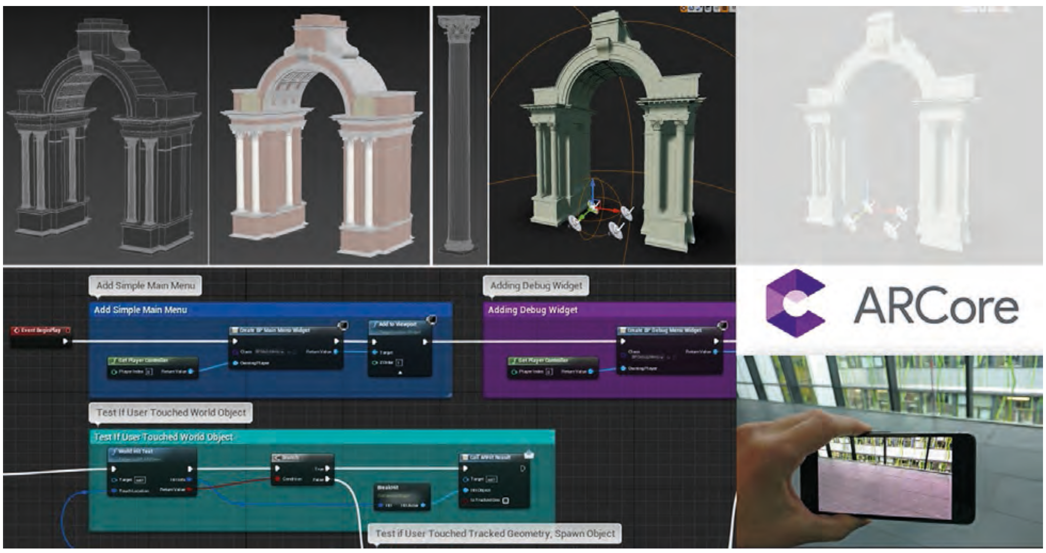

Fig. 2. Above, optimization of the 3D Model and creation of Assets; below, Implementation of the plan recognition system for AR applications (by Aniello Pascale).

Fig. 3. From left, Micco Spadaro (XVII secolo), *Punizione dei ladri al tempo di Masaniello*; Insertion test of the artefact in the original site.

via Toledo, the artefact was positioned. After recognizing the support surface's height, the operator could place the artefact easily and explore it from the most congenial point of view. During the experience, the sounds, located almost under the arch, helped to realize what Porta Toledo's installation must have been, in the place where it was designed (fig. 3).

Conclusions

On the basis of the sources collected and through the discipline of drawing, this paper analyzes the project of the 'Pubbliche feste [...]' by Gaetano Barba (1791). Accompanied by unpublished graphic elaborations, the paper describes the architectural elements that make up the celebration through an 'augmented' design. In this sense, the virtual reconstruction of the entrance door on Via Toledo and its implementation in an Augmented Reality application was proposed as an application case. The choice to contextualize AR to the current urban situation instead of set it in the late eighteenth century results from the fact that the research group is analyzing the design and reconstruction of other eighteenth–century Neapolitan celebrations. Therefore, the reconstruction of the eighteenth–century city will be formulated as future works where will be evaluated the different urban places, sometimes, modified in relation to the ephemeral architectures construction.

Notes

[1] The research presented is the result of the joint work of the five authors. The paragraphs *Introduction* and *Conclusions* is written by Ornella Zerlenga and Luigi Maffei; the paragraph *The drawing of the ephemeral: the regulating principle of the 1971 celebration in Naples by Gaetano Barba* by Vincenzo Cirillo and the paragraph *The prototype of the application in AR* by Massimiliano Masullo and Aniello Pascale.

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Authors
Ornella Zerlenga, Dept. of Architecture and Industrial Design, University of Campania Luigi Vanvitelli, ornella.zerlenga@unicampania.it
Vincenzo Cirillo, Dept. of Architecture and Industrial Design, University of Campania Luigi Vanvitelli, vincenzo.cirillo@unicampania.it
Massimiliano Masullo, Dept. of Arch. and Industrial Design, University of Campania Luigi Vanvitelli, massimiliano.masullo@unicampania.it
Aniello Pascale, Dept. of Architecture and Industrial Design, University of Campania Luigi Vanvitelli, aniello.pascale@unicampania.it
Luigi Maffei, Dept. of Architecture and Industrial Design, University of Campania Luigi Vanvitelli, luigi.maffei@unicampania.it

 Isbn 9788835125280

AR&AI classification and 3D analysis

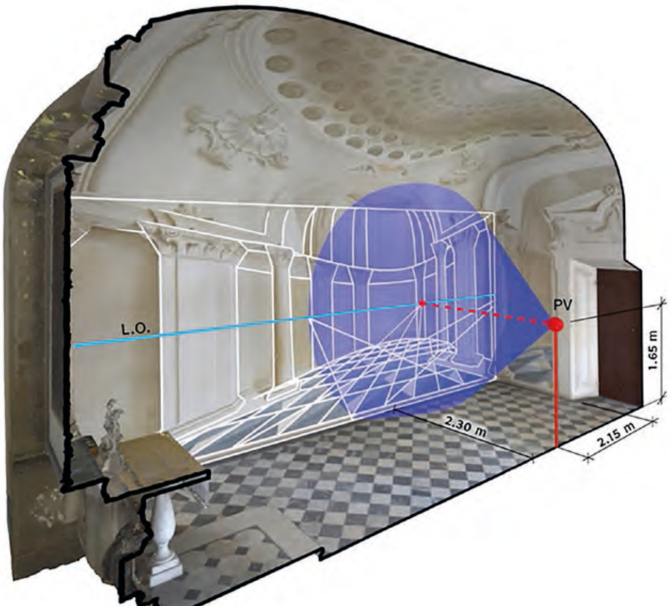
Immersive Technologies for the Museum of the Charterhouse of Calci

Marco Giorgio Bevilacqua
Anthony Fedeli
Federico Capriuoli
Antonella Gioli
Cosimo Monteleone
Andrea Piemonte

Abstract

The Charterhouse of Pisa in Calci, one of the most important monasteries in Tuscany, now houses two important museums: the Natural History Museum of the University of Pisa and the National Museum of the Monumental Charterhouse of Calci. While the Natural History Museum has recently enriched its collection by offering structured and differentiated visits based on user type, the offerings of the Museum of the Monumental Charterhouse are not sufficiently adequate to meet the great historical value of the complex. This contribution therefore presents the first results of a project aimed at enhancing visits to the National Museum of the Charterhouse using immersive technologies. The project envisages the definition of a new visit path, modifying the current path and integrating it with immersive experiences of video mapping, VR/AR, sound immersion, informative totems, audio–visual supports, and multisensory activities.

Keywords
Charterhouse of Calci, VR/AR, video mapping, 3D modeling, immersive experience.



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Introduction

Recent studies demonstrate how immersive technologies based on augmented, real, and mixed reality are currently and widely used in the fruition of cultural heritage (Bekele et al. 2018). In the field of fruition of monuments and museal spaces, these technologies provide solutions enabling patrons to view 3D digital models of cultural artifacts and to interact with them in a variety of ways, enhancing their involvement (Trunfio et al. 2021). Most of these applications enjoy continuous evolution in the fields of 3D digital survey, modeling, and graphics. AR applications, virtual reconstructions, video mapping, etc. are, in fact, widely used to enhance visiting experiences, as well as serving as tools for promotion and enhancement of cultural heritage. In Italy, there are several noteworthy cases, such as those of the Virtual Archaeological Museum of Herculaneum, the Egyptian Museum of Turin, and the National Archaeological Museum of Naples, the AR/VR applications at the Baths of Caracalla and the Ara Pacis in Rome, and the video mappings in the Imperial Forums in Rome, to name but a few.

This contribution intends to present the first results of a project aimed at enhancing the tour of the National Museum of the Monumental Charterhouse of Calci using immersive technologies. The project envisaged the definition of a new visit path, modifying the current one and integrating it with immersive experiences of video mapping, VR/AR, sound immersion, information totems, audio–visual supports, and multisensory activities.

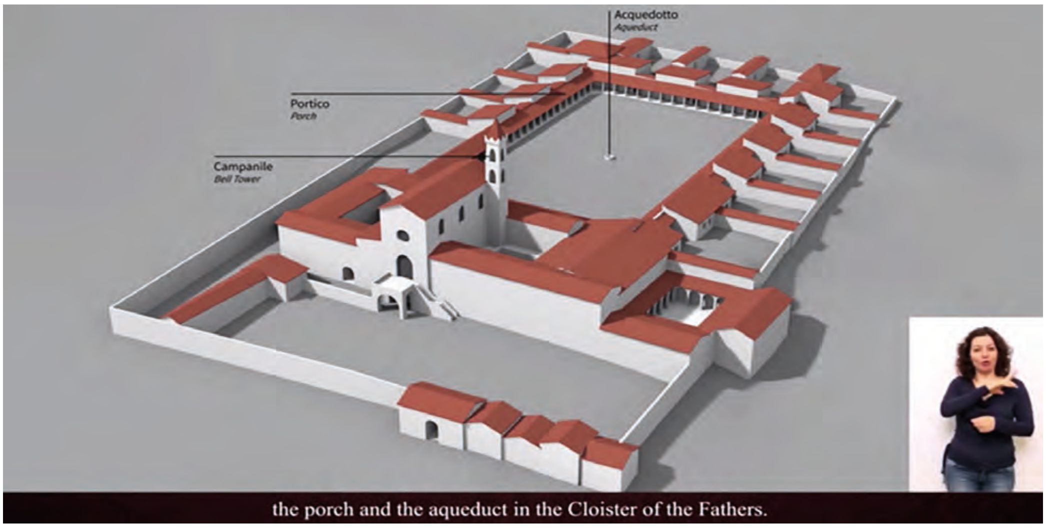

Fig. 1. Frame of the introductive video projected in the Chapel of San Sebastiano (elaborations by A. Fedeli).

The Case Study: the Museum of the Monumental Charterhouse of Calci

Founded in 1360 on the slopes of Monte Pisano, the Charterhouse of Pisa in Calci represents one of the most significant monasteries in Tuscany. The charterhouse is the result of several modifications and extensions documented from its founding to the end of the 18th century and reflects the strict rules of the Carthusian Order [Piombanti 1884; Manghi 1911, Giusti & Lazzarini 1993]. It represents an ideal semi–urban 'village' in which hermit and cenobitic life are harmoniously blended. The *correria*, the *coenobium*, and the *desertum* are distributed following the idea of a gradual separation of the fathers from the common life. The large Courtyard of Honor separates the entrance and the *correria* from the *coenobium* and the church; this is placed in a central position emphasizing the compositional axis of the entire complex. On the southern side of the church, there are spaces dedicated to the life of the religious community (minor cloisters, refectory, *colloquium*, and chapter room), the noble guesthouse, and the grand ducal apartments. The northern side boasts several buildings originally used for agricultural activities. The Great Cloister with the cells of Fathers completes the system on the eastern side.

In 1962 the religious community left the Charterhouse of Calci. Since 1972, the complex has hosted the National Museum of the Monumental Charterhouse of Calci, under the control of

the Ministry of Culture and, since 1978, the Natural History Museum of the University of Pisa. The National Museum of the Monumental Charterhouse offers visits to the monumental spaces of the monastery: the church, the refectory, the chapter room, the noble guesthouse, the grand ducal apartments, the pharmacy, and one of the fathers' cells. The Natural History Museum occupies most of the service buildings on the northern side of the complex.
The Natural History Museum has recently enriched its collection and provides customized visits based on user type; meanwhile, the current offerings of the Museum of the Monumental Charterhouse aren't sufficiently adequate to the great historical value of the complex, presenting critical issues: some of the most important spaces are not visitable, visits are organized in staggered guided tours, and contents are oversimplified.
In 2018, the University of Pisa funded an interdisciplinary research project aimed at the conservation and enhancement of the Charterhouse [1]. More than 15 research units participated in the project, developing research in several fields, from historical analysis to specialized studies, such as those relating to fire prevention and accessibility.
As part of the project, in addition to a campaign of digital surveys and an in–depth historical study, the work we present here was developed, aimed at enhancing visits to the National Museum of the Charterhouse through immersive experiences of augmented and virtual reality.

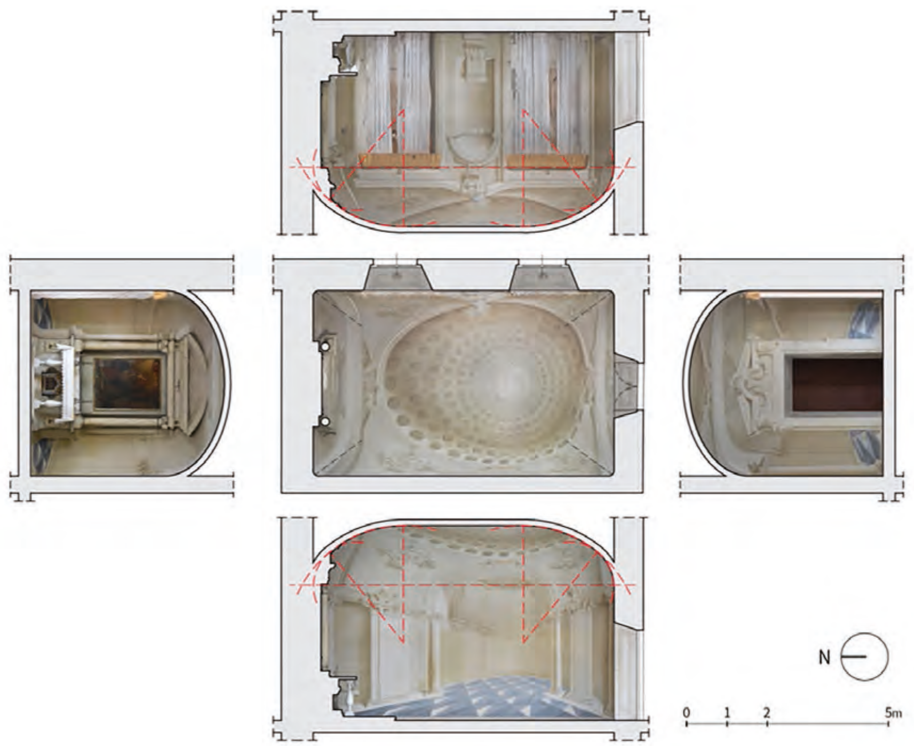

Fig. 2. Orthophotos of the frescoes in the Chapel of St. Anthony (elaborations by A. Fedeli).

The Project for a New Guided Tour of the Museum of the Charterhouse of Calci

The project was structured in two phases. The first concerned preliminary analysis for the development of the project. In addition to a study of the state of the art in the field of VR/AR use in museum environments, the tour path currently active in the museum was analyzed to highlight its problems and potential. The results of the in–depth historical research on the Charterhouse, developed under the coordination of Ewa Karwacka within the project funded by the University of Pisa, provided the definition of objectives and contents of the new visit tour. Specifically, it was decided to focus the tour on the monastery's evolutionary phases, on its most valuable decorative and architectural elements, and on the figures who, over time, had a prominent role in the history of the Charterhouse.
The second phase concerned the development of the project. The new guided tour is based on the current one but modifies its route, expanding the number of spaces that can be visited

and increasing the immersive involvement of visitors, who are left free to move along the path using an audio–video guide. The guide can be downloaded on tablets or smartphones and provides information on the spaces and their locations. Each space features an informative totem, and sound atmospheres are envisaged to amplify the sense of interaction.
Access is scheduled at set times for groups of people who, once their entrance tickets have been paid, can wait for their turn in the nearby San Sebastiano Chapel, appropriately rearranged for the projection of an introductory video on the history of the Charterhouse and the life of the monastic community.
All the spaces are classified into three categories based on the information that will be provided: art and architecture, monastic life, and mixed information. In some spaces, experiences of virtual and augmented reality, video mapping, or multisensorial experiences are provided. All the applications are accessible for deaf people as well, through a guide in Italian sign language.
Once the general visit program was defined, some of the augmented reality applications were developed: the introductory video projected in the Chapel of San Sebastiano, the virtual reality experience in the Chapel of Sant'Antonio, and that in the Cloister of the Chapter [2].
For the development of the applications, realistic 3D models were created on the basis of the results of the surveys carried out with LIDAR and 3D photogrammetric methodology by the ASTRO Laboratory within the activities of the project funded by the University of Pisa. Models were developed with the open–source software Blender. The informative texts, based on the original results of the historical research, were processed with Audacity, a software for editing and audio recording. The final processing was developed in graphic animation software including Adobe After Effects for the introductory video in the Chapel of San Sebastiano, and Unreal Engine for the immersive experiences in the Chapel of Sant'Antonio and in the Cloister of the Chapter.

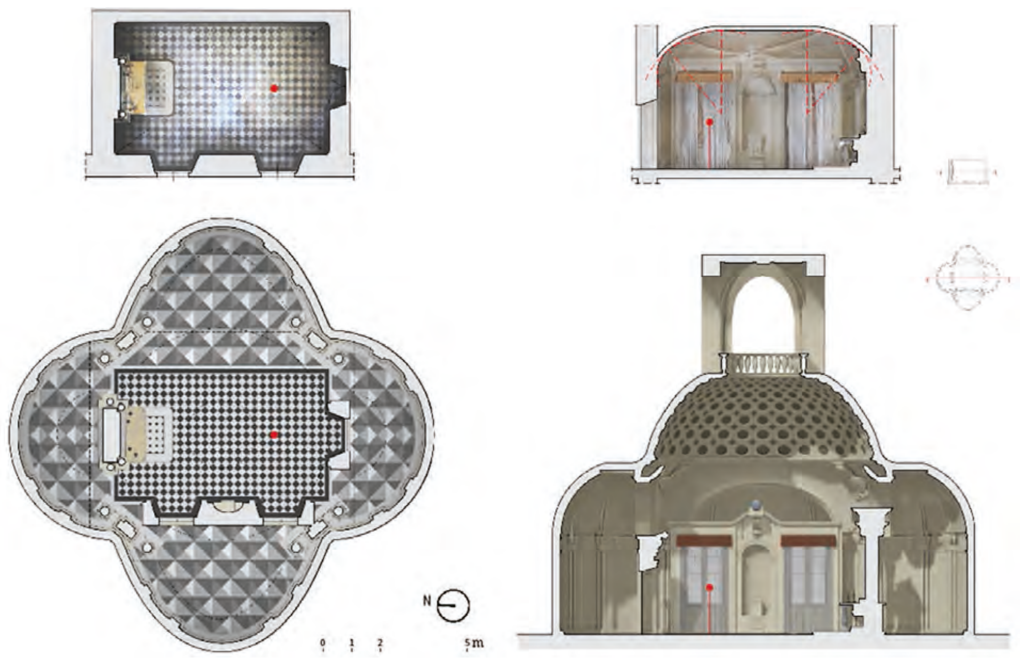

Fig. 3. Comparison between real space – on the top – and illusory one – on the bottom – in the Chapel of Sant'Antonio. Plan and longitudinal section (elaborations by A. Fedeli).

Immersive Experiences at the Museum of the Charterhouse of Calci

The first digital application developed was the introductory video projected in the Chapel of San Sebastiano for visitors waiting for entry. The historical research developed in the project of the University of Pisa identified, in chronological order, the most significant events that affected the Charterhouse from the day of its founding to today. The video presents a graphic animation of 3D models that reproduce an external view of the various construction phases of the complex. Information pop–ups superimposed on the video help to point out the buildings as they are being described in Italian by the narrator voice. Subtitles scroll

for the translation of the text into various languages; a small panel in the lower corner of the screen is dedicated to the video guide in Italian Sign Language for deaf visitors (fig. 1).
The second application concerns the experience of virtual reality in the chapel of Sant'Antonio, characterized by the quadraturist frescoes by Pasquale Cioffo, a Neapolitan painter very active in Pisa in the second half of the 18th century. The experience focuses on quadraturist painting techniques, explaining the geometric principles underlying the representation and providing a 3D reconstruction of the illusory space depicted (fig. in cover page), inside which the visitor is immersed thanks to the use of a VR headset. Wearing the headset, visitors find themselves inside a high–resolution 3D reconstruction of the real environment, created thanks to 3D photogrammetry techniques (fig. 2); the narrator voice explains what is being observed. Subsequently, the real environment changes and the reconstruction of the illusory space imagined by Cioffo appears (fig. 3). The story then focuses on the optical phenomenon of anamorphosis, found on one of the sides of the chapel.
The last application is the virtual reality of the Cloister of the Chapter, also to be experienced with a VR headset. In this case, the viewer is immersed in virtual spaces that depict the layout of the cloister in the most important historical phases; a narrator voice accompanies the visitor during the experience. The development of the application required a preliminary reconstruction of the 3D models that describe the various evolutionary phases.

Conclusions

The project aimed to investigate the potential in the application of new AR/VR technologies to the specific case of the Charterhouse of Pisa in Calci. This work was also an opportunity to study a communication strategy for the results of the research project funded by the University of Pisa with particular reference to that of the historical/critical study. The first results obtained in this phase are functional to the search for funding for the realization of the project as a whole and of the specific applications.

Notes

[1] The research is part of the biannual research project "Studi conoscitivi e ricerche per la conservazione e la valorizzazione del Complesso della Certosa di Calci e dei suoi Poli Museali" financed by the University of Pisa in 2018 and 2019, coordinated by M.G. Bevilacqua. The authors wish to thank Ewa Karwacka, Elisabetta Pozzobon and Stefano Aiello, director of the National Museum of the Charterhouse of Calci, for their support and collaboration.

[2] Video demonstrations of the applications are available at the following links: https://www.youtube.com/watch?v=haLQXXsLZ_k (Chapel of San Sebastiano), https://www.youtube.com/watch?v=pPZuzoBbaRQ (Chapel of Sant'Antonio), https://www.youtube.com/watch?v=f4vtJ0BrqMw (Cloister of the Chapter).

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Authors
Marco Giorgio Bevilacqua, Dept. of Energy, System, Territory and Construction Engineering, University of Pisa, marco.giorgio.bevilacqua@unipi.it
Anthony Fedeli, Dept.of Energy, System, Territory and Construction Engineering, University of Pisa, anthonyfedeli@gmail.com
Federico Capriuoli, ACAS3D Soluzioni Digitali s.r.l., federico.capriuoli@acas3d.com
Antonella Gioli, Dept. of Civilisations and Forms of Knowledge, University of Pisa, antonella.gioli@unipi.it
Cosimo Monteleone, Dept. of Civil, Environmental and Architectural Engineering, University of Padua, cosimo.monteleone@unipd.it
Andrea Piemonte, Dept. of Civil and Industrial Engineering, University of Pisa, andrea.piemonte@unipi.it

 Isbn 9788835125280

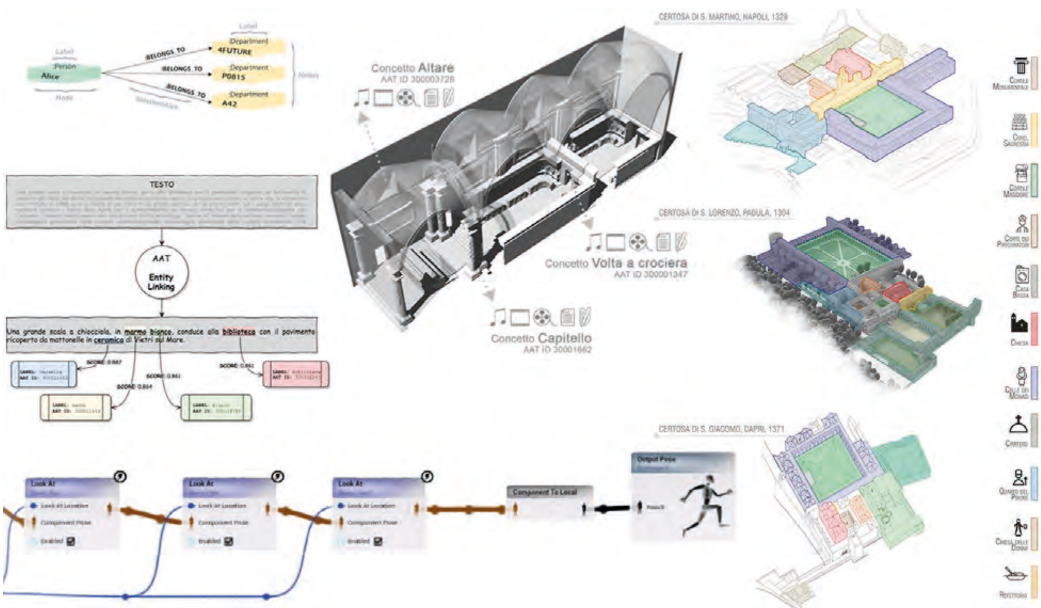
CHROME Project: Representation and Survey for AI Development

Massimiliano Campi
Valeria Cera
Francesco Cutugno
Antonella di Luggo
Domenico Iovane
Antonio Origlia

Abstract

The paper shows the results of the PRIN CHROME Cultural Heritage Orienting Multimodal Experiences project, about the three charterhouses of Campania, with a specific focus on research activities related to the connections between representation, survey, AI and VR. The project has formalized a methodology of collection, analysis and modeling of multimodal data, useful for designing virtual agents in 3D environments, which can be applicable in museum environments. The achievement of the goal is pursued through: (i) an integrated range–based acquisition and morphometric data modeling process coherent with VR management, (ii) the use of semantic maps linked with thesauri published as LOD to solve both the theme of ambiguity and annotation uncertainty and the interpretability of information by an AI; (iii) the modeling of a virtual agent with the development of a mathematical model for computational control of gestures and prosody.

Keywords
semantic annotation, artificial intelligence, Unreal Engine 4, graph databases.



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The CHROME Project: Methodology and Procedures

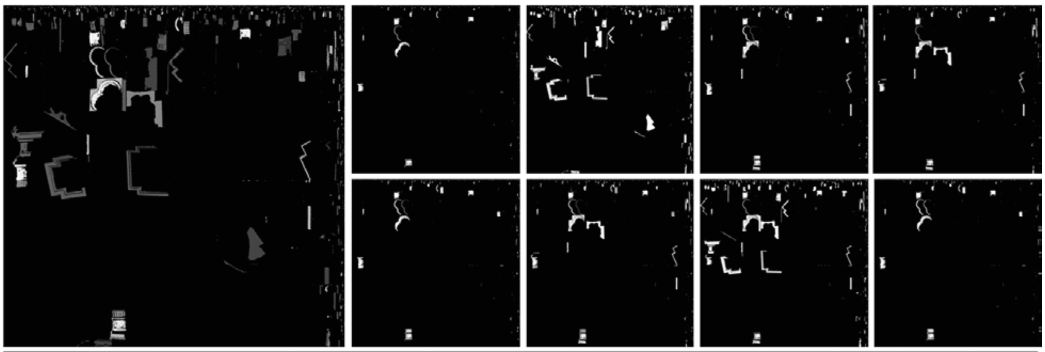
The paper shows the specific results of the PRIN 2015 CHROME Cultural Heritage Resources Orienting Multimodal Experiences, developed around the case studies of the three charterhouses of Campania, with the focus on research activities related to the connections between representation, survey, artificial intelligence and virtual reality [1].
The project, that is strongly inter–disciplinary, has formalized procedures for collecting, annotating and analyzing multimodal data – such as written texts, oral presentations, 3D models – for a subsequent use by the AI.
In particular, the resources collected and annotated have served to design a virtual agent inserted in 3D virtual scenarios. This Virtual agent can be applicable in museum environments and joins the tour guides increasing the potential for intervention on the public visiting cultural sites. The virtual agent, in fact, simulates social signals through computational control of gestures and prosody according to a mathematical model based on the behavior of operators specialized in the communication of cultural contents.
The base knowledge has therefore been structured in order to build a model that allows to compose a not default and potentially adaptable to the type of interlocutor oral presentation. The achievement of the goal was pursued through the semantic association of the whole corpus of information to the geometric entities of the spatial model, that are digital clone of the real good to which the enhancement is addressed. The annotation of 3D representations made it possible to link the presentation to the automatic selection of the auxiliary material and to query it with a natural language dialogue system, in which the information is spatialized. As disclosed here, attention is focused on those investigative activities related to the interconnections gained between the disciplinary of representation and survey and the domain of computer science, related to each other and put at the service of the development of AI applications in augmented and virtual reality environments.
Since this background, the specific research investigated the theoretical and methodological issues related to the geometric and semantic manipulation of digital representations of architectures or rather, on one hand, those of a terminological–significant nature and, on the other, the ones of geometric–formal matrix. The first ones involve the process of meaning assigning to spatial forms, the latter concern both the processes of "construction" of the digital clone and the method by which recognizing on it the geometric boundary of semantic concepts. In addition, the considered segmentation approaches have been strictly aimed at storing content in an AI–questionable system, made able to disseminate information in digital settings that can be experienced through AR/VR technologies. This last aspect involved a reflection upon the most appropriate ways of graphic simplification of the elements of the heritage in order to make their vision fluid in a system of virtual use without losing neither the realistic rendering nor the understanding of the contents.

Representation for Semantic Structuring and Knowledge Formalization

The first phase of the study involved the realization of the digital virtual scene, to be semantically annotated, for subsequent use by the AI.
For the three case studies of the project, the charterhouse of San Martino in Naples, the San Lorenzo one in Padula and the San Giacomo one in Capri, important campaigns have been carried out. These have seen the integration of passive and active optical sensors in order to achieve accurate, precise and photorealistic three–dimensional models, returning both of the overall morphology of the different convents and the complexity of the decorative details of the interiors.
Starting from the integrated range–based acquisition of morpho–metric data, point clouds were modeled with classic triangulation algorithms and subsequent texture projection. The models obtained from the multi scalar survey were then developed for rendering in intensive 3D application development environments, initially subjecting them to a process of selective decimation of the level of detail to make their vision fluid and then subjecting them to a process of texture baking to not lose their realistic output or the understanding of the contents.

To link 3D models to the AI, annotations have been added or rather questionable metadata that encodes the knowledge of domain experts independently of applications.
In relation to domain vocabulary, the art and architecture thesaurus that is a standard of the architecture world formalized by the Getty Institute as Linked Open Data, was chosen in a format designed for compatibility with triple RDF, a flexible and extensible graph structure. The AAT has allowed to solve lexical ambiguities and to be used as a link between different data sources to allow AI to efficiently cross–check information, such as coming from Wikidata.
In order to associate semantic concepts with the corresponding spatial forms, a method that uses the correspondence between 2D/3D space, coding the annotation in the form of maps has been developed. In particular, once analysed the 3D twin and identified the semantic concepts found in it, these were searched in the Getty thesaurus to recognize its unique id code in the domain. Subsequently, for each significant and present in the model term of the is realized a monochrome map in which white indicates the polygons detected for the given concept and black does not show any relevance. The map is applied to the digital representation as well as a texture. In this way the information related to the process of attribution of meaning to spatial forms is translated into a purely visual image [Cera 2018]. The possibility of using a grey scale allows to refine the quality of information where the gradations have different percentages of relevance. So, this method makes it possible to consider semantic maps produced by multiple domain experts obtaining a final map of their degree of agreement, calculating the average values for each UV coordinate (fig.1).

single session annotation workshop
2 restorers [Re], 2 architecture historians [Sa], 2 art historians [St], 2 surveyors [Ri], 2 geometry experts [Ge], 2 echnologists [Te], 2 designers [Pr]



	Ge1_C04_bmp	Ge2_C04_bmp	Pr1_C04_bmp	Pr2_C04_bmp	Re1_C04_bmp	Re2_C04_bmp	Ri1_C04_bmp	Ri2_C04_bmp	Sa1_C04_bmp	Sa2_C04_bmp	St1_C04_bmp	St2_C04_bmp	Te1_C04_bmp	Te2_C04_bmp
Ge1_C04_bmp	1,0000	0,9859	0,6434	0,6550	0,0175	0,2873	0,7705	0,8680	0,6543	0,9427	0,7012	0,7015	0,7090	0,8249
Ge2_C04_bmp	-	1,0000	0,6502	0,6625	0,0188	0,2907	0,7790	0,8505	0,6605	0,9529	0,6840	0,6852	0,6851	0,8349
Pr1_C04_bmp	-	-	1,0000	0,4637	0,5276	0,6905	0,5467	0,5190	0,4627	0,6753	0,3816	0,3812	0,3858	0,5854
Pr2_C04_bmp	-	-	-	1,0000	0,0163	0,0174	0,8854	0,7055	0,9921	0,6818	0,8279	0,8283	0,8375	0,7906
Re1_C04_bmp	-	-	-	-	1,0000	0,8835	0,0191	0,0230	0,0163	0,0110	0,0195	0,0196	0,0193	0,0205
Re2_C04_bmp	-	-	-	-	-	1,0000	0,1002	0,1513	0,0168	0,3059	0,0211	0,0208	0,0206	0,1753
Ri1_C04_bmp	-	-	-	-		-	1,0000	0,8297	0,8851	0,8034	0,7350	0,7359	0,7441	0,9311
Ri2_C04_bmp	-	-	-	-		-	-	1,0000	0,7038	0,7637	0,8274	0,8266	0,8352	0,8912
Sa1_C04_bmp	-	-	-	-		-	-	-	1,0000	0,6864	0,8247	0,8248	0,8340	0,7897
Sa2_C04_bmp	-	-	-	-		-	-	-	-	1,0000	0,5654	0,5654	0,5719	0,8582
St1_C04_bmp	-	-	-	-		-	-	-	-	-	1,0000	0,9919	0,9831	0,6593
St2_C04_bmp	-	-	-	-		-	-	-	-	-	-	1,0000	0,9893	0,6587
Te1_C04_bmp	-	-	-	-		-	-	-	-	-	-	-	1,0000	0,6661
Te2_C04_bmp	-	-	-	-		-	-	-	-	-	-	-	-	1,0000

Fig. 1. Semantic maps produced by different annotators for the concept of capital. Calculation of the degree of agreement with its final map.

The innovative thing of coding and using semantic maps lies in allowing to manage annotation margin of error, which is almost always ignored in the usual processes of semantic segmentation of digital representations. The margin of error of domain experts is, on the contrary, a substantial element in the knowledge process where it provides knowledge and complex cognitive mechanisms. For example, using this procedure, the margin of error due to the annotator's background, is not only recorded but also turned into a resource.
Machine learning approaches, in fact, are based on statistical models that, in this case, should model the probability of each geometric element belonging to a given category. Discretizing, in representation, is equivalent to removing information from the data on which the model is build, thus imposing a 'filtered' view to the algorithm, which has no way of modelling the existence of concepts which, for example, fade into each other or whose definition depends on multiple factors, such as the specialization of the domain expert in charge of the annotation, the aim of segmentation, the support on which the recognition process is implemented, etc. [Cera 2019].

From Survey to Development of Artificial Intelligence

The semantic maps gathered with AAT codes, make the information contained in the map cross–referenced with that contained in the other resources annotated such as in the texts, in the AAT itself and in other LODs.
To make access to information fast and efficient for interactive applications that use real–time 3D material, knowledge has been depicted within a graph database [Webber 2012], which drastically reduces latency due to querying online resources, for example in RDF format. This allows to quickly cross–check information from different sources and compare it to adequately support the application.
Within a set of reference texts, the same concepts, described in geometry by semantic maps have been identified and annotated. In this way, you can associate, with the text that describes a resource, the geometry to which it refers independently of the application, making the material highly reusable for different purposes.
One of the possible applications achievable with the type of annotated material is the development of conversational virtual agents placed in an environment about which they have sufficient knowledge to interact with them. To study the behavior that these agents should take, a corpus [Origlia 2018] of 12 hours of audiovisual material was collected to document the behavior of art historians who illustrate the environments of the charterhouse di San Martino to small groups of visitors.
A linguistic and psychological annotation system has been created to cross–check the various levels of communication through which an experienced human transmits cultural content.
In the laboratory, motion capture data was collected to map human movements to 3D avatars. The logic of managing the gestures of the virtual agent has been defined as follows: at each frame, the system calculates the position to be assumed on the basis of a series of animations that are combined according to a series of parameters. As far as the gestures of the arms are concerned, there is a dedicated state machine which places the agent in a 'neutral' position. When an externally produced signal arrives, which corresponds to the start of an audio containing a synthetic voice, the agent switches to 'talking' mode. During speaking mode, an external system may require highlighting concepts with varying degrees of 'strength' or pointing in a certain direction. Since the location of the virtual agent is known, the only information you need to control its gestures is the location of the target.
Using the centroid of the mass of points labeled with a certain concept, for example "altare maggiore" imagining that the virtual agent is placed in the church of San Martino, it is possible to calculate the angle between the virtual agent and the concept that you want to point, thus providing the animation control system with the missing information to produce coherent dectic gestures.
The processing pipeline that allows an AI to interact is made of several modules.
First of all, a specially trained neural network transcribes audio containing a user's voice. From this transcription, an 'intent' is extracted, that is the abstract intention of the speaker and any parameters that detail the request. Based on intent and parameters, a graph database query is produced to extract the content needed to fulfill a request. The sentence to be synthesized is then passed to a second neural network that synthesizes the audio and produces the accompanying information, such as the phonetic annotation of the audio file, to allow the control of lipsync, and the indication of the temporal position of the expressed concepts, to control the gestures of the deictics. Based on this information, an interaction management engine delivers the presentation in real time.

Results

The research developed as part of the CHROME project provided an opportunity to investigate the increasingly structured interconnections between the field of representation and survey and the themes of information technology. In particular, the paper analysed the role that the specification of architectural survey and the forms of drawing play in the development of AI applications tested in the dissemination of cultural contents related to some architectural

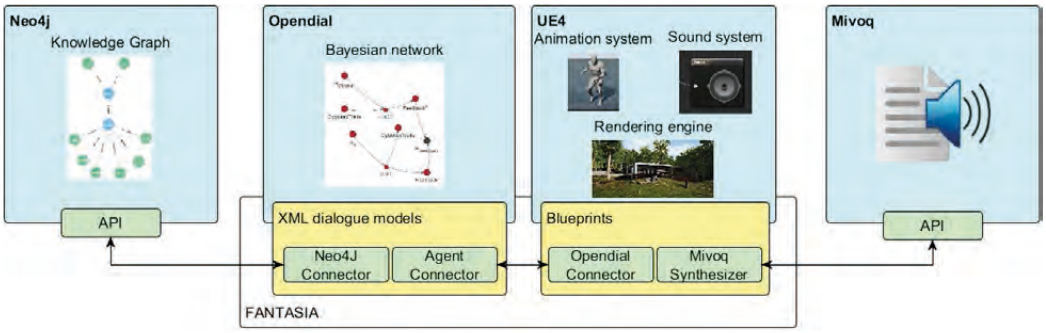


Fig. 2. The original FANTASIA architecture. An updated version was used in this work.

heritage of Campania. Validated on the case studies of the three charterhouses, the project developed a method of collection, analysis and dissemination of spatialized information resources around three–dimensional architectural models, used in digital environments whose presentation is entrusted to virtual agents modelled on human behavior.
CHROME's system architecture is designed to be generalized in a framework called FANTASIA [Origlia 2019] for developing conversational virtual agents that can be applied in any museum environment and therefore replicable (fig.2). The architecture uses graph databases to link data from different sources such as LOD, three–dimensional models, or other. It enables the use of modern peripheral devices and third–party services for capturing and analyzing input signals and integrates probabilistic decision–making systems for controlling interaction in 3D environments.

Notes

[1] The PI of the Italian PRIN project CHROME #B52F15000450001 is prof. F. Cutugno. The architecture unit was coordinated by profs. M. Campi and A. di Luggo. Arch. D. Iovane worked on architectural data acquisition together with arch. V. Cera who developed the research on semantics. Dr. A. Origlia worked on the A.I. development.

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Authors
Massimiliano Campi, Dept.of Architecture, University of Naples Federico II, campi@unina.it
Valeria Cera, Dept. of Architecture, University of Naples Federico II, valeria.cera@unina.it
Francesco Cutugno, Dept. of Electrical Engineering and Information Technology, University of Naples Federico II
Antonella di Luggo, Dept. of Architecture, University of Naples Federico II, antonella.diluggo@unina.it
Domenico Iovane, Dept. of Architecture, University of Naples Federico II, domenico.iovane@unina.it
Antonio Origlia, Dept. of Electrical Engineering and Information Technology, University of Naples Federico II, antorio.origlia@unina.it

Isbn 9788835125280

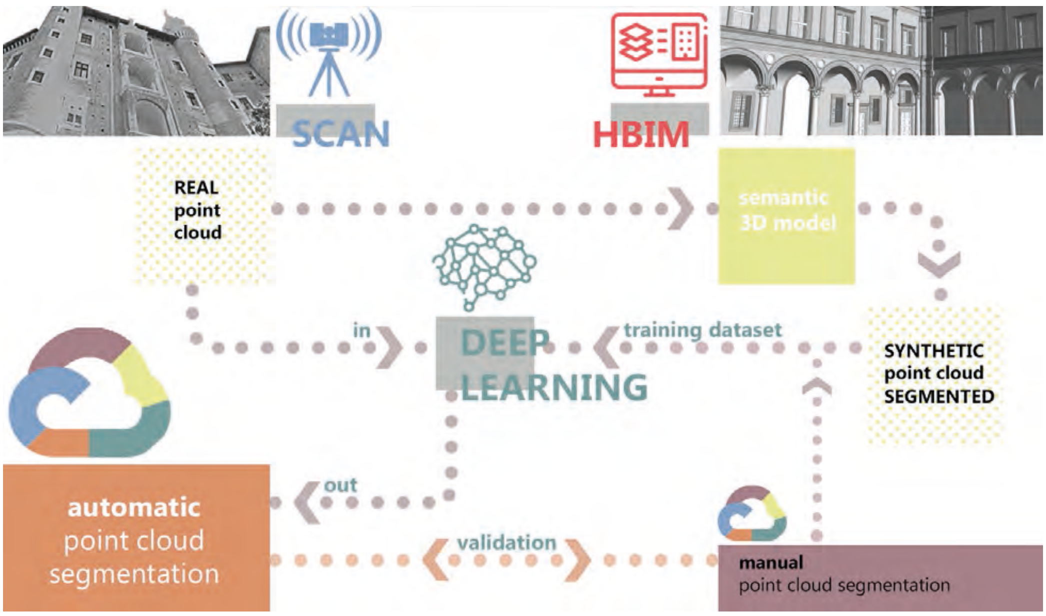
Deep Learning for Point Clouds Classification in the Ducal Palace at Urbino

Paolo Clini
Roberto Pierdicca
Ramona Quattrini
Emanuele Frontoni
Romina Nespeca

Abstract

Starting from a multi–scalar and multi–dimensional survey, most interdisciplinary researches, based on representation, are becoming a tool for dialogue between the new trends of Artificial Intelligence (AI) and the most compelling needs of our CH. The approach here proposed stems from the desire to understand how much of the skills useful in architecture analysing and modelling can be made available to the "machine", with the goal to accelerate cognitive or management processes. Some HBIM models, as an existing digital heritage, were used to obtain the semantic intelligence. From this specialised intelligence comes a cyclical path which, through AI, transforms this knowledge into new forms of collective intelligence, at the service of the heritage. The paper presents a research that brings very promising results for the segmentation of point clouds and the facilitation of ScanToHBIM approaches, made possible by the large amount of data acquired on the Ducal Palace of Urbino.

Keywords
semantic segmentation, AI, intelligent models, HBIM, collective intelligence.



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Introduction

The Digital Cultural Heritage (DCH) stands today as a cornerstone in the processes of Built and Museum Heritage management and knowledge but also in its conservation. Starting from the current practices of multi–scalar and multi–dimensional survey, ranging from landscape and monumental heritage to artworks, the interdisciplinary research, based on representation, is becoming a tool for dialogue between the new trends of Artificial Intelligence (AI) and the most compelling needs of our heritage.
In the field of CH, AI applications are dealing with both enabling new forms of digital data management, both generating digital assets from existing ones, with a surprising capacity of mimesis. However, a theoretical debate on the implications of AI in the context of Digital Humanities and Computational Modelling is still lacking.
The approach here proposed stems from the desire to understand how much of the skills useful in architecture analysing and modelling, inherent to the drawing discipline, can be made available to the 'machine', with the goal to accelerate cognitive or management processes with regard to the built heritage. Some HBIM models, considered as an existing digital heritage, were used to obtain the semantic intelligence. From this specialised intelligence comes a cyclical path which, through AI, transforms this knowledge into new forms of collective intelligence, at the service of the heritage.
The work is part of a broader strand of research in DCH by UNIVPM, now significantly developed in the strategic University project CIVITAS which addresses several challenges related to museums and the historical buildings.

State of the Art

The architectural heritage documentation is based on point clouds, with accurate discrete databases. However, in order to become effective, they need an informed and structured representation, mandatory based on semantic subdivision. For this reason, point clouds are often used, within BIM software, as a starting point for building parametric 3D, which incorporates semantic information and where architectural elements are identified and enriched with non–geometric information. This process, namely ScanToBIM, is costly and requires skilled operators.
The SACHER project obtained interesting BIM–independent results in the use of segmented 3D data [Bertacchi et al. 2018, pp. 283-288], while the INCEPTION projects [Iadanza et al. 2019, pp. 381-388] and the BIM3DSG platform [Rechichi et al. 2016, pp. 703-710] achieved to interoperate and manage knowledge outside BIM platforms.
The need to automate, at least partially, the ScanToBIM process is largely agreed, certainly not in order to diminish the designer's knowledge but to make the whole process more agile focusing on new research challenges. Mainly the backbone is to make models more intelligent and aware of their nature.
An important step is the semantic segmentation, facilitating the identification of different types of architectural elements in the point clouds. It implies classifying each point to a particular type of object (e.g. wall, roof, column, vault, etc.). While Machine and Deep Learning techniques are spreading in every field, even at the basis of 'popular' applications with images labelling, point clouds make the task much more complex, especially when point clouds pertain to historical architecture. Machine Learning is also giving satisfactory results for datasets with different accuracies and hierarchical procedures [Teruggi et al. 2020, p. 2598]. To date deep learning is particularly challenging for classical architecture, due to the complexity of shapes and the limited repeatability of elements, making it difficult to define common patterns within the same class of elements [Pierdicca et al. 2020].

The CIVITAS Project and Multi–Scalar Acquisition in the Ducal Palace at Urbino

The paper presents a research that brings very promising results for the segmentation of point clouds and the facilitation of ScanToHBIM approaches, made possible by the large amount of data acquired on the Ducal Palace of Urbino and the collection of the National

Gallery of the Marche region. The digitisation phase of the building and museum artefacts is a fundamental step of the CIVITAS project, as detailed in [Clini et al. 2020, pp.194-228]. One of the challenges, in particular, is the optimisation of data management dealing with HBIM exploiting Linked Data, Semantic Web and Artificial Intelligence technologies, in order to perform new workflow starting from reality–based informed models.
The acquisitions implemented for the Ducal Palace of Urbino were based on a multi–scale approach, as highlighted in [Nespeca 2018, pp. 1-14]: they tested various types of instrumental acquisition and defined the most appropriate levels of detail for the various forms of representation and features of the building. All the interior rooms and courtyards, but also the exterior of the building, were digitised with TLS, merged on a general 3D model acquired with Mobile Mapping and assisted by a campaign of spherical panoramas.
For many paintings and sculptures of the collection and for the Duke's *Studiolo*, dedicated photogrammetric acquisitions were deployed (fig. 1), to complete the set of acquisitions. In this way, a comprehensive three–dimensional mapping was conducted, which forms the basis for any scientifically based action in the process of digital transformation of museums.

Semantic Segmentation by Deep Learning Approach

The point clouds, with the various gathered accuracies (fig. 2), constitute a high–quality morphometric model, but the nature and pertinence of the single points to the different components of the architecture is inferred by humans. Till recently the subdivision of point clouds was mostly based on algorithmic or manual approaches, now the possibilities granted by neural networks lead to exploit them to recognise points and assign them a semantics consistent with the rules of the architecture.
The identification of classes, which also has theoretical implications of great interest, has proved to be fundamental in the methodology. Following an analysis of coherence with the existing and consolidated thesauri and considering the historical period, its morphological–formal language and the features of the acquired data, a first level scale of the semantic hierarchy was defined (fig. 3).
The state of preservation of the building gives reason to expect very good correspondences with 'ideal' forms. The subsampling required to perform several tests and in several epochs, with an average computational capacity, also led to the choice of working on the most general level of the main architectural members.
A bottleneck in Deep Learning approaches applied to CH is the absence of sufficiently large annotated data sets that can allow the training of the networks. Thus, the approach took advantage of many previous models developed with semantic structuring features: from the Palladio Library villa models developed in 2012 to the most recent HBIM models (Ferretti Palace, Santa Maria of Portonovo and Ducal Palace). In addition, parametric models present

Fig. 1. Outputs of SfM surveys: bas relief by Francesco di Giorgio Martini and Duke's Studiolo

on the web were used and appropriately selected, as well as the HBIM core of the Honour Courtyard of Laurana. This allowed the generation of a sufficiently large data set of synthetic clouds to train the neural network. This phase therefore places drawing knowledge at the centre and the intelligence present in the models is regenerated and acquires new life and unexpected opportunities for value.
All the chosen models had the common characteristic of being organised according to a shapes grammar in which the constituent ontologies of the architectures had been analysed and studied. In the models, the classes were also consistent with those of the point clouds that were to be segmented, both in terms of formal qualities and hierarchical articulation. All models were stored in the various formats (.rvt, .3dm, .kmz) and archived in a file format that incorporated the taxonomy by naming the layers. This enabled the export in .obj format and the subsequent creation of semantically structured synthetic point clouds.
At this point, the workflow for the Deep Learning approach foresees firstly the training of the neural network, i.e. its training, and then the experimentation on a never observed dataset. The DGCNN network was chosen, which is based on the EdgeConv operation, and also a refinement of it RaDGCNN, as better detailed in [Morbidoni et al. 2020a; 2020b].
Two experiments were performed on two different case studies: in the first one, we used the TLS point cloud of the courtyard of the Ducal Palace of Urbino to evaluate the trained models, trying to identify 8 different classes of architectural elements. For consistency, the synthetic point cloud derived from the HBIM model of the Ducal Palace of Urbino was removed from our training set.
In the second experiment we evaluated the models trained on the TLS point cloud of Ferretti Palace. In this case we removed the BIM model from the training set. Since two of the selected architectural element classes (column and pillar) are not present in the building, in this case we try to recognise the remaining 6 classes.
The results, reported here in qualitative form (fig. 4), allow us to conclude so far that the use of synthetic data can be effective in the automatic segmentation of TLS point clouds. Of course, this is only a first step and an encouraging scenario to be explored and analysed with other applications to support the ScanToBIM process of historic buildings.

Conclusions

In this article, a method, still in the process of being perfected, oriented towards the instruction of artificial intelligence for the segmentation of point clouds has been described: that is, an attempt has been made to improve the discernment capacities of neural networks, helping them with a form of collective intelligence built from the disciplinary foundations of design. These results in themselves constitute an interesting and novel approach, especially if we consider the potential for use and re–use of existing models, generated over the last 40 years or more, in terms of interoperability and sustainability of digitisation; but also in terms of formulating the axiom of digital heritage in itself, not as a mere copy.

Fig. 2. Point clouds of the Ducal Palace at Urbino.

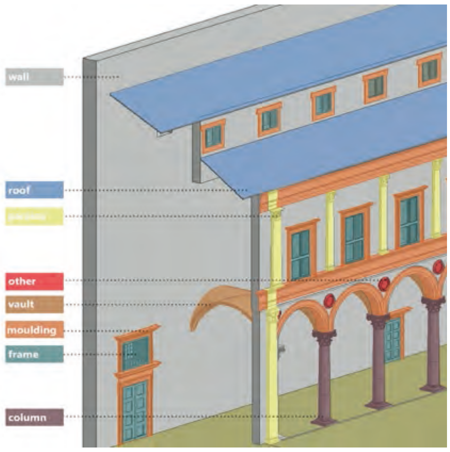

Fig. 3. Identification of classes in the taxonomy about the Honour Courtyard of Ducal Palace.

Fig. 4. Qualitative results about the segmentation of point clouds for the Ducal Palace.

Another interesting food for thought comes from the essay [Clivaz 2020, pp. 67-73] in which Robert Wachal's 1971 text is recalled. He raises what he sees as the main problem of the humanistic approach to computer science: to hope that the time will soon come when humanists will start asking new questions, also referring to artificial intelligence. Clivaz, too, emphasises that his 'personal vision' is an open appeal worthy of the attention of scholars today. So, also for us, CH experts, it is perhaps time to turn the telescope upside down: to start asking artificial intelligence new questions, the questions posed with increasing urgency by a fragile heritage.

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Authors

Paolo Clini, Dept.of Civil Engineering, Construction and Architecture, Polytechnic University of Marche, p.clini@univpm.it
Roberto Pierdicca, Dept. of Civil Engineering, Construction and Architecture, Polytechnic University of Marche, r.pierdicca@univpm.it
Ramona Quattrini, Dept. of Civil Engineering, Construction and Architecture, Polytechnic University of Marche, r.quattrini@univpm.it
Emanuele Frontoni, Dept.of Information Engineering, Polytechnic University of Marche, e.frontoni@univpm.it
Romina Nespeca, Dept. of Civil Engineering, Construction and Architecture, Polytechnic University of Marche, r.nespeca@univpm.it

Isbn 9788835125280

Automated Modelling of Masonry Walls: a ML and AR Approach

Pierpaolo D'Agostino
Federico Minelli

Abstract

A methodology for the automated delineation of brick masonries from images to a vector representation is discussed in this paper. Python environment is chosen for the coding activity in order to provide automation to the process. Edge detection and vector delineation of brick joints are followed by a phase of brick clustering for masonry classification. The implementation of the process is tested on a video sequence to simulate an augmented reality application for masonry detection.

Keywords
masonry delineation, Canny algorithm, AR, digital survey.

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Introduction

Parametric and algorithmic modeling are constantly becoming increasingly useful tools for the automation of processes destined, among other things, to the management and use of cultural heritage, in particular taking into account the digital evolution that the tools for its recovery and restoration have had, opening up to the implementation of techniques such as machine learning and augmented reality. Particularly in the Italian context, in fact, it is known how vast is the heritage worthy of attention for its redevelopment and restoration, both for historical buildings and for modernist buildings that also have valuable characteristics. Clearly, it is in this direction that the new frontiers of digital surveying are evolving by the possibility of describing the artifacts through their "digital twins" and by their direct use rather than for the realization of classic technical drawings.
Digital survey is often indicated as a starting point for the creation of structured data models. In fact, nowadays their use in reverse engineering processes is stable, but still partly subject to manual modeling (according to the interpretation of a human being).
In this spirit of participation in the automation of such processes, we are working on automated workflows for the digitization and interactive use of historical and cultural heritage that exploit machine learning applications to obtain cognitive feedback in real time from the architectural artefact. To this end, augmented reality applications, running on handheld devices used as virtual reality interfaces, can mimic the human presence in space and provide a computer–generated model, in a virtual space, modeled on the real context, with which the users can interact.
The research in progress, taking advantage of an approach specifically base on scripting, concerns the digitization of masonry, a so often required specification that could be very complex to reach as automatic outcome, especially in historic buildings where different construction techniques can be implemented, to extract adequate information to classify and model the underlying structure (fig. 1).

Fig. 1. Real cases of exposed masonry: Cellammare Palace (on the left) and the 'Sferisterio' in Fuorigrotta (on the right) in Naples.

The delineation based on images or video streams of the masonry, in particular, is centered on "edge detection" to identify the key areas of the masonry structure: firstly, the regions where the joints between the bricks are located. This is a fundamental step for the masonry morphology classification process as it allows the segmentation of single bricks.
To obtain a vector representation of the masonry, in order to achieve a referred 3D modeling, it is crucial to define horizontal and vertical joints between the bricks, detected and delineated from the contours. These operations are pointed to find the intersection points between the lines in order to outline the contours of each brick and, then, to evaluate the area of each closed boundary used to classify and reconstruct the masonry structure. Machine learning techniques come into play in this classification phase and in particular, an approach based on data clustering is implemented for the recognition of bricks with faces of different dimensions exposed. The methodological approach is described below.

The ability to carry out this operation in real time and in an unsupervised way opens up the integration of the model thus obtained with augmented reality systems. Multi–channeling through the use of augmented reality thus finds an interesting development path with high added value since the quality and quantity of data acquired and processed to support the interaction enrich the experience of interaction with the monument by placing it in an ideal context: real–time feedback of the architecture. The fundamental innovation, in fact, regardless of the scale dimensions of the displays (tablets, smartphones) is the activation of the development of an integrated interaction project which, by exploiting augmented reality, enhances communication and knowledge, managing to simplify and make the interaction with architecture more complete and engaging, raising the level of attention (fig. 2).

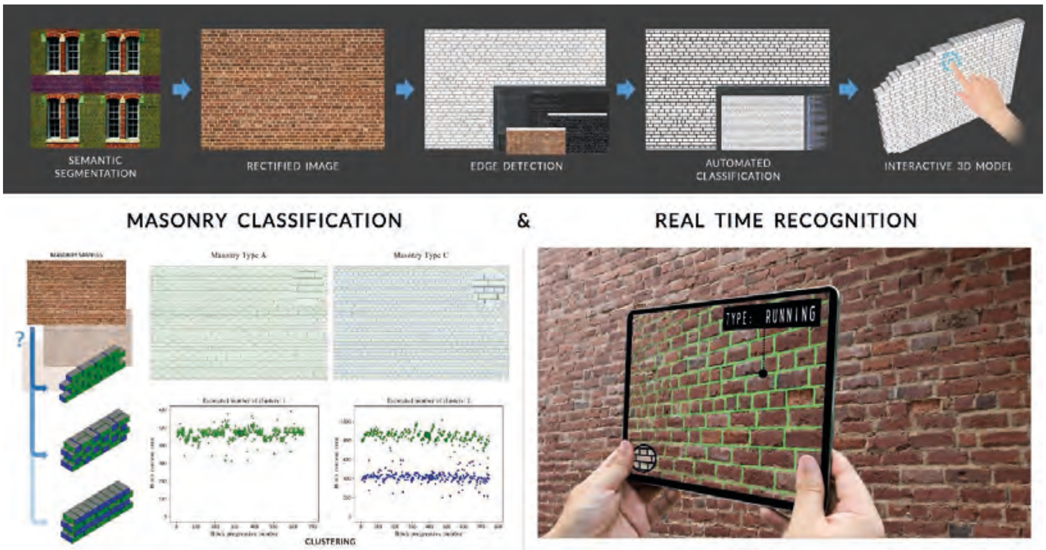

Fig. 2. Layout of the proposed workflow.

Methodology

What we would describe here is a workflow for automatic detection and modeling of periodic walls. We started by considering how to apply parametric and algorithmic modeling in such automation processes used to take.
The possibility in objective processes that allow automatically to pass from the point cloud to parametric models is still very rare, for example in Building Information Modeling approaches, for which the possibility of identifying, for example, openings or automatically segmenting building components is still an arduous challenge. Or, for example, in the models intended for the detailed analysis of its parts (for example FEM analysis), of those characteristics that make up the individual construction components.
Starting from simulated data but corresponding to possible applications starting from real data, the process leads to the production of solid models of brick walls. The theoretical approach aims to be applied in several city models applications. Procedural city modeling ranges from the digital reconstruction of entire neighborhoods to the production of single building models [Zhu et al. 2016]. From the analysis of available studies on digital reconstruction of urban areas using algorithmic procedures [Musialski et al. 2013] and automated as–built modeling [Patraucean et al. 2015] our modeling approach can be evaluated with these methods. The usage of images and point clouds for the recognition and modeling of architectural features are of great interest and in continuous development. The automation of this parametric architecture modeling process from on–site survey materials is also a very active field in scientific research today [Czerniawski and Leite 2020]. However, differently by standardized situations, the morphology of building walls can be very complex, especially in historic buildings, but several techniques can be implemented to extract adequate information to classify and model the underlying structure. The image–based delineation of masonry, in particular, relies on edge detection to identify key areas of the masonry structure: first,

the regions where the gaps between the bricks are located. This is a fundamental step for the masonry morphology classification process as it allows the segmentation of single bricks, but the subsequent 3D modeling phase also requires an investigation as it allows to obtain a full reconstruction of the asset [D'Agostino & Minelli 2020].
Moreover, this work focuses on the automatic detection of masonry from images and its interaction in AR applications. To answer to the goal of optimization of the ongoing investigation in this connection between AR acquiring process and a future–proof real time processing, with the need to test several outcomes, an image–based approach to vectorization of wall textures characterized by horizontal rows is delineated and tested on different masonry samples. The programming language Python is selected, for its flexibility and effectiveness for code writing activities in order to achieve process automation, for the coding activities to achieve the automation of the process.
The work specifically aims to digitally reconstruct the masonry walls based exclusively on rectified images. As anticipated, the approach proposed first seeks to achieve a vector representation of each brick in respect of the real masonry texture. The second purpose, rarely addressed in the literature before, is to create an interactive delineation of masonry on the basis of the current arrangement of the bricks. The approach tries to be effective on masonry made by bricks of a single size.
Segmentation and three–dimensionality for the reconstruction of the individual bricks is tested on several images of masonry to verify the consistency of the proposed workflow to the unpredictable conditions that can occur when dealing with real masonry. The RGB source images are transformed into the HSV color representation in the Canny algorithm for the first brick edge detection. The binary image of the edges is used to extract the contours of the brick. In order to obtain a vector representation of the masonry, the UV coordinates of the edges of the horizontal brick joints are first detected and delineated by the contours. The vertical joints are detected in a second step and added to the previous one, respecting the height of each row of bricks. The intersection points between the lines allow to outline the contours of each brick. The area value of each closed contour is calculated to classify and reconstruct the masonry structure.
Mean Shift algorithm is used to sort the outlines of the front bricks by the outlines of the side facing ones. The quantity of clusters detected and the number of occurrences of front and side bricks allows to classify each masonry analyzed in one of the 3 categories investigated in this work (fig. 3). Finally, a reconstruction of the 3D mesh of the masonry is performed and the geometric model is saved in a DXF file.
A data clustering approach is implemented for recognizing bricks with faces of different sizes exposed. The Mean Shift clustering algorithm is then used to separate the oriented bricks with the front face in view from the side ones, based on the area value of their respective boundaries. The front facing bricks, in fact, show a lower value of the boundary area, while the side facing bricks are characterized by a greater value of the boundary area. Choosing the Mean

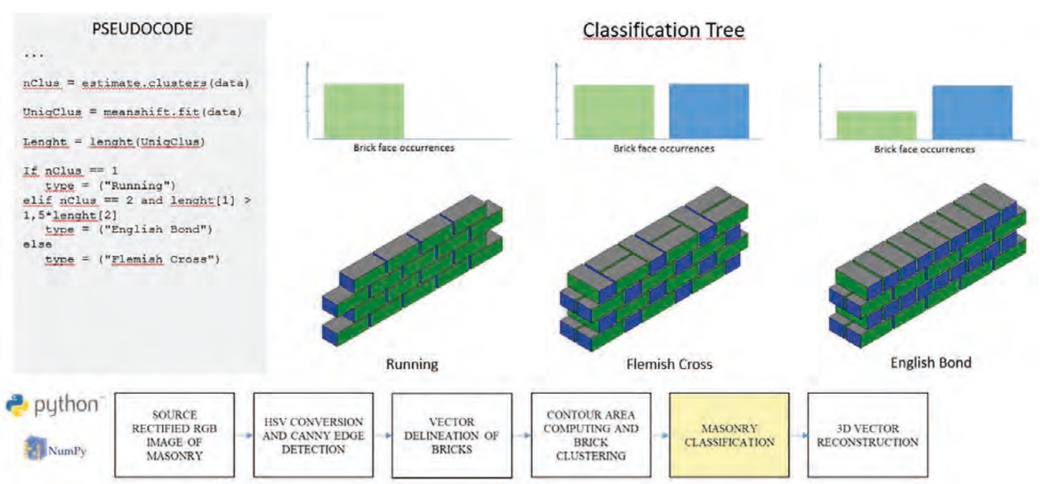

Fig. 3. The masonry classification process: brick face occurences detection to define the wall textures.

Shift clustering algorithm relies on its ability to directly estimate the number of clusters from the dataset. In fact, other clustering algorithms require the user to manually specify the cluster number file to search for in the dataset. The masonry investigated in this study, however, range from types in which a single cluster of bricks is found to types in which two clusters occur.
Deepening the possibility to join AR visual acquisition with the described workflow, we propose that the vectorization of walls' joints could pass for their identification directly on visual flows. So, the approach studied for raster images is applied to video sequences in order to allow a real time detection and vectorization of the masonry. An augmented reality application is therefore simulated on a video stream, acquired in real circumstances (fig. in cover page). An effective delineation of horizontal rows is obtained with robust outcomes on several frames of the video stream. This opens to the complete vectorization of the masonry in real time, that will be addressed in future studies.

Conclusions

Multi–channeling through the use of augmented reality thus finds an interesting development path with high added value because the quality and quantity of data designed to support the interaction enrich the experience by placing it in an ideal context: when needed and to whom really need.
The fundamental issue, in fact, is not so many the scale dimensions of the displays (mega–screen, tablet, installation, smartphone) that make the difference, as the development of an integrated communication project which, by exploiting augmented reality, enhances communication by managing to simplify and make the interaction more complete and engaging, raising the level of attention.
Segmentation and three–dimensionality applied in wall digitation is tested on a video of the masonry to verify the consistency of the proposed workflow to the unpredictable conditions that can occur when dealing with real masonry.
The results obtained in the study can be applied in architecture surveys and fruition application to establish a direct connection between the captured image and the reconstructed geometry. Practical applications of this procedure can also be found in the automated BIM modeling process for 3D reconstruction of buildings from survey material and in the automated FEM modeling of masonry structures, as it can provide a detailed model of masonry morphology.
Future work should consist of further experimentation on different and more complex masonry structures to obtain results of wider applicability. The masonry classification, already attained with images, should be also tested on video sequences.

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Authors
Pierpaolo D'Agostino, Dept. of Civil, Building and Environmental Engineering, University of Naples Federico II, pierpaolo.dagostino@unina.it
Federico Minelli, Dept. of Industrial Engineering, University of Naples Federico II, federico.minelli@unina.it

 Isbn 9788835125280

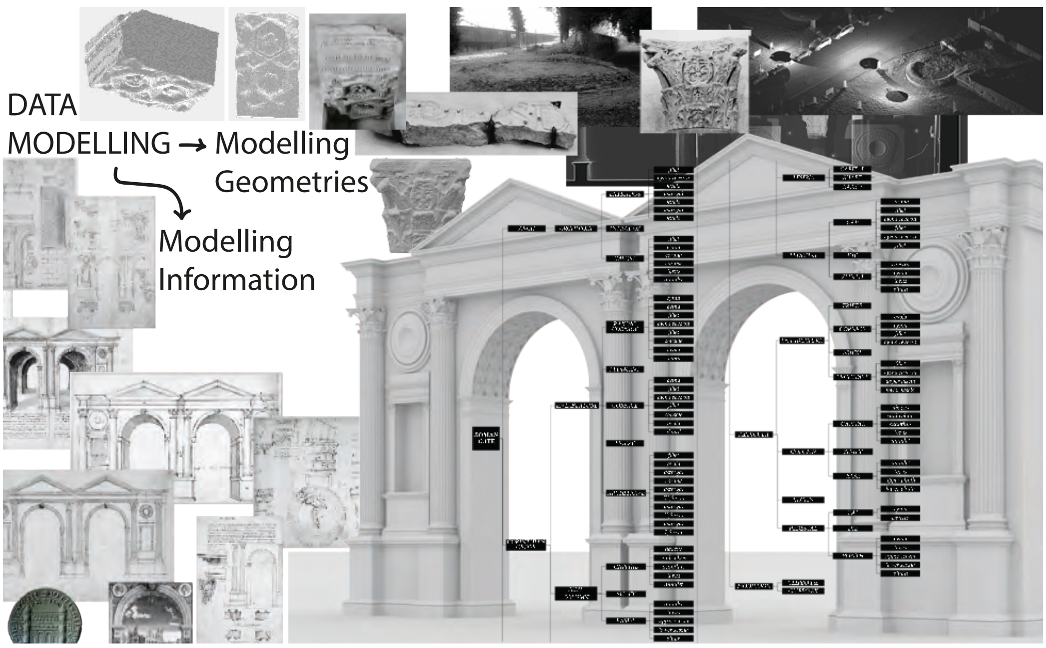
Data Modelling in Architecture: Digital Architectural Representations

Elisabetta Caterina Giovannini

Abstract

Digital Architectural Representations represent the most fruitful field of research of the last decade. Digital technologies and the use of internet in architectural representation shows how 3D visualization combined with storytelling can help to spread scientific knowledge over the web.These new technologies also affect the way of thinking 3D models, how to design them and how to build their related knowledge with the purpose of future reuse of information and data.
The paper is focused on the analysis of current methodologies and workflows for data modelling in Architecture to better understand the potential of using standards in the 3D modelling sector with a focus on cultural and architectural heritage.

Keywords
3D models, semantics, data models, standards, ontologies.



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The Complexity of Digital Architectural Representations

Since the '90s of the last century, with the advent of computers, information technologies and computer–aided design (CAD) systems have seen the beginning of the use of digital models in archaeology and architecture [Boccon–Gibod, Golvin 1990; Frischer 2006; Reilly 1991]. The use of these three–dimensional models, which I like to define as digital representations of architecture, poses nowadays, unlike in the past, some questions about the meaning and the scientific value [Borra 2004; Borghini, Carlani 2011; Dell'Unto et al. 2013] that they assume for diverse target audiences.
In the field of architectural heritage and more specifically in the field of virtual reconstructions, starting from historical documentation, it seems evident that alongside geometric modelling, the presence of diverse data and documents prefigure the need for the definition on an informative model that should assist the geometric modelling and that should make explicit the series of processes related to the critical interpretation of data and information available [McCurdy 2010; Apollonio, Giovannini 2015; Brunke 2017]. Different interpretative and cognitive processes can be considered similar to algorithms "a procedure used to return a solution to a question through a set of well–defined instructions" [Tedeschi, Andreani 2014]. The difference from the mathematical algorithm definition is that, in this case, the set of instructions are generally not stated and that the interpretative algorithm can generate several outputs (diverse hypothetical reconstructions) starting from the same series of input (knowledge available).
A Three–dimensional model became then, a digital architectural representation of the n digital representations that can be generated by human processes of interpretation. Analyzing the type of input of the three–dimensional reconstruction process, we can see how these interpretative processes are linked to the qualitative and quantitative values of the available documentation. This type of data and information support both geometric and informative modelling, considered as two indivisible and inter–related components of the same process. An example of that is the common practice of using the semantic architectural structure to digitally create the parts of a 3D model according to logics proper of the architectural field and to use digital architectural elements as reference objects to connect additional information [De Luca 2013; Giovannini 2017; Quattrini, Battini, Mammoli 2018]. A digital architectural representation can be, then, considered as a visual and graphical expression of an interpretative activity and a constitutive element of knowledge production. This assumption is valid not only for 3D models but also for all human objects of production that can be manuscripts, sketches, drawings, maquettes, etc. These pre–existing data can then be used for information modelling and three–dimensional modelling enriching diverse Levels of Knowledge (LoK).

Knowledge Representation in Architecture

Applications of Artificial Intelligence (AI) to Cultural Heritage (CH) have been developed with a varying fortune to produce innovative tools for documenting, managing, and visiting cultural heritage. From the representation of cultural history, digital semantic archives, tools to support visitor's interpretation, augmented reality and robotics, the application of AI has been applied to the whole humanistic area. In the Architectural Heritage field, AI is commonly used for storytelling, restoration analysis and 3D model classification. AI is also used to develop ontologies [1] to allow computers to perform automated reasoning about data and information all over the world. Software Engineering, on the other hand, started to use conceptual modelling as a representation of a system to describe concepts. Tools for designing and creation of online visualization of data, according to the rules that govern the web in the past, and more recently the semantic–web cannot avoid the use of Information modelling to manage and structure data and information. In the case of digital architectural representations, the text analysis and the source where architecture is represented in a bi–dimensional way are enriched by three–dimensional information derived from the digital acquisition or three–dimensional modelling. The recent need for interoperable processes that characterize most of the research on documentation and representation of architectural heritage has emphasized the occurrence of various approaches. Some studies analyze conceptual modelling to define and reorganize the information and material available for the comprehensive use of a digital asset. The theme of processes in digital modelling is useful to trace choices, decisions on three–dimensional models using visualization codes [De Kramer 2020; Giovannini 2020; Apollonio, Gaiani, Sun 2013]. Declaring the accuracy or reliability of 3D models [Apollonio et al. 2017; Bianchini, Nicastro 2018] including those obtained using tools and algorithms (for example in the case of digital survey or photogrammetric acquisition) is a practice mostly used in approaches for geomatics and Building Information Modelling applied to Heritage (H–BIM) [Maiezza 2019; Garagnani 2013; Quattrini, Pierdicca, Morbidoni 2017]. Resource–based 3D modelling considered as interpretative process, differs from digital acquisition where reality–based data can be considered as formal derivation of the original object. Both modelling processes are in relation since the 3D reality–based data, if present, affects the modelling and validation process of the derived resource–based model. Standards and models for information modelling including conceptual ones have long been in use in the cultural heritage sector: the CIDOC Conceptual Reference Model (CRM) standard [2], the ISO 21127:2014 also known as CIDOC–CRM , often associated with the controlled vocabulary of the Getty Institute (AAT) [3], is the most used ones. Recent trends demonstrate that ontologies and conceptual models are not that different,

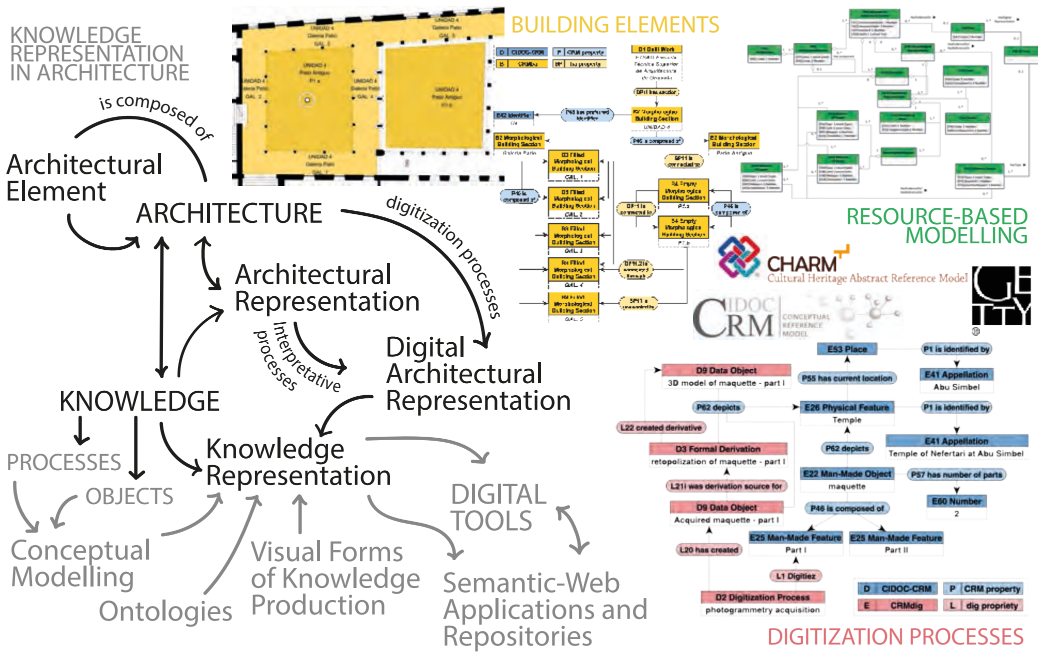

Fig. 1. Conceptual data modelling overview. On the top, conceptual modelling of H–BIM object classes using CRMba extension. On the top–right, resource–based modelling processes using CHARM model. On the bottom–right a conceptual model for the reality–based 3D modelling process using CRMdig extension. On the left, conceptual representation of knowledge in the Architectural field.

and that combined can allow standardising the documentation of cultural heritage. In the archaeological field the Cultural Heritage Abstract Reference Model (CHARM) [4] is an ontology for cultural heritage expressed in Conceptual Modelling Language (ConML) [Gonzalez–Perez et al. 2012]. The Extended Matrix (EM) [5] is a visual language of knowledge representation in the field of virtual reconstructions with a stratigraphic approach [Demetrescu 2015]. In the architecture, engineering and construction (AEC) industry, the reference standard is the Industry Foundation Classes (IFC) data model [6], a metadata schema capable of describing architectural semantics and making Building Information Modelling (BIM) models interoperable between different software solutions. The IFC guarantees the management of geometry but it does not allow the addition of customized information outside the context of the construction industry. Nevertheless, some emerging research proposes an IFC classification for architectural heritage asset

[Diara, Rinaudo 2020] or an architectural heritage semantic 3D documentation for the reusability of 3D city models [Noardo 2018]. To establish a dialogue between the architectural field and the cultural heritage assets a recent study proposes a conceptual model based on the CIDOC–CRM standard to describe a building in its parts, as encoded by a BIM software using the CIDOC–CRMba extension [7], developed to describe built archaeology [Parisi, Lo Turco, Giovannini 2019]. With that model, it was possible to describe the morphological elements that characterize a building but it fails in describing the link between the geometric parts and their spatial coordinates. The conclusion was partially acceptable if we think that the CIDOC–CRM was born to describe assets about museum collections and not about architecture.

Conclusions

Considering the diverse research conducted, the possibility of creating conceptual models capable of managing three–dimensional data and descriptive metadata on the documentation of architectural heritage is still missing. The CRM–dig [8], a CIDOC–CRM extension, is a model capable to manage the complexity of the reality–based data acquisition, but it does not clarify and explain the relationships between the source used, the data extracted from it and its use for geometrical modelling. The IFC, on the other hand, can be used to describe geometric information of BIM or H–BIM models. The challenge is to create an efficient data model that allows semantic traceability of data. A novel semantic organization of data is necessary for the development, of platforms, analysis tools and algorithms able to manage structured data, make queries for different purposes in complementary disciplinary domains emphasising their combined potential. There is a need for a common conceptual model that reflects the complexity of the three–dimensional modelling process. Conceptual modelling should focus on the representation of architecture in all its forms (drawings, surveys, digital models) and should represent both digital and physical properties. A conceptual reference model for the digital representation of architecture (fig. 1) should first identify the architectural evidence, built, or only represented ones, the parts of which it can be composed and how these can be digitally represented. The knowledge about an architectural asset is also composed of a set of resources that also need to be digitized and that contribute to the creation of the "architectural" digital asset. Then the relationship between digitized resources and three–dimensional modelling can take place by mapping diverse interpretative and modelling processes creating different levels of knowledge. The knowledge produced, can then be used by digital tools able to read the conceptual grammar of the asset: an information system in which three–dimensional models and historical documentation is collected and organized. To reuse data, data models are necessary and even if they do not follow standards, they must at least be stated because this is how computational technologies and machine can see the human world.

Notes

[1] Ontology is the theory and the Information Model is the application. Information modelling is here intended as "a representation of concepts, relationships, constraints, rules, and operations to specify data semantics for a chosen domain of discourse. The advantage of using an information model is that it can provide sharable, stable, and organized structure of information requirements for the domain context." [Lee 1999]

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Author

Elisabetta Caterina Giovannini, Dept. of Architecture and Design, Politecnico di Torino, elisabettacaterina.giovannini@polito.it

Isbn 9788835125280

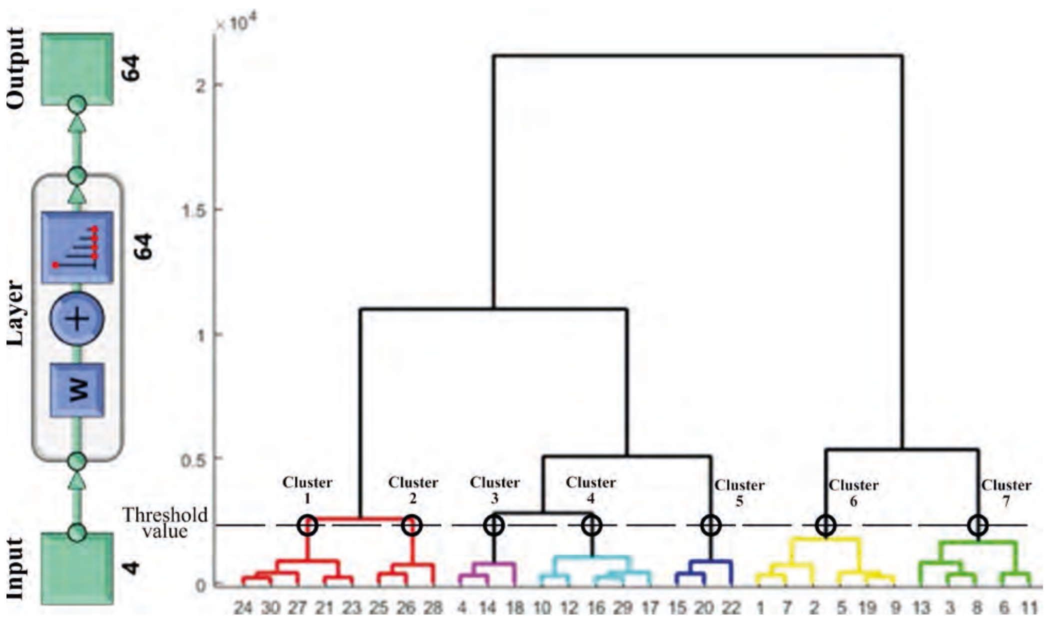
Image–Based Modelling Restitution: Pipeline for Accuracy Optimisation

Marco Limongiello
Lucas Matias Gujski

Abstract

The paper presents an innovative approach to support survey methods by applying AI algorithms to improve the accuracy of point clouds generated from UAV imagery. The work analyses different photogrammetric accuracy parameters in a first step, such as reprojection error and the intersection angle between homologous rays, verifying that a single parameter is enough to evaluate the accuracy of the photogrammetric restitution. Therefore, some of the calculated parameters were analysed through a Self–Organizing Map (SOM) to reach a compromise between the value of the variables analysed and the noise reduction associated with the 3D model definition. In the case study, it has been observed that the parameter that most influences the noise in the photogrammetric point clouds is the intersection angle.

Keywords
UAV, photogrammetry, accuracy, point cloud, SOM.



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Introduction

During the past ten years, the application of photogrammetry in digital 3D recording has grown greatly. In fact, due to the development of the Computer Vision technology and the Structure of Motion (SfM) algorithms, the processing time of the mostly automatised photogrammetric workflow has accelerated exponentially, solving what was once a well–known weakness [Falkingham 2012, pp. 1-15]. In addition, thanks to their technological development, the Unmanned Aerial Vehicles (UAV) have become easier to pilot and more reliable, a fact that indirectly promotes the growth of the photogrammetric applications, especially at a medium and large scale. Due to the acquisition speed and the transportability of the vehicle, the technology is indeed very versatile, allowing these instruments to be used in different applications [Fernández–Hernandez 2014, pp. 128-145].
A topic debated in the scientific world is the evaluation of the accuracy of point clouds, particularly of the Tie points (TP), generated by processing either UAV or terrestrial, also known as Close Range images. A low accuracy of the model may, in fact, invalidate the high resolution of the data, thereby vitiating the graphic scale and derived products (i.e., plan, section, elevation). Especially in the Cultural Heritage sector, the accuracy of the metric system must be evaluated too, in order to avoid 'incorrect' documentation from the metric perspective.
A sparse point cloud just composed of TPs is the first stage to obtain a complete 3D model; however, it is obvious that there are lower quality TPs. It is therefore appropriate to delete them to not affect the results of the subsequent steps. Most photogrammetric software offers the possibility to filter the TPs only based on an estimation of the Reprojection Error (RE) parameter associated with each TP [Barba 2019, pp. 1-19].
In this work we propose an algorithm and a clustering method based on the Self–Organizing Maps (SOM), a type of neural network trained using unsupervised learning to produce a representation (usually a two–dimensional map) of the input data space.
SOM was needed to select the groups of points with similar characteristics that produce more noise, so to obtain a TP cloud containing just the points with greater accuracy. The subdivision of the TP cloud into different clusters made possible its discretization into different accuracy classes, which can be activated or not according to the level of detail to be pursued.

Case Study and Data Acquisition

The case study considered to develop this work is the Norman–Swabian Castle of Vibo Valentia, surveyed using a UAV in 2017. Currently, the castle hosts the Archaeological Museum 'Vito Capialbi' and the provincial offices of the Department of Cultural Heritage. The UAV system used for this application is a DJI Inspire with a net weight of the sensor of about 3 kg. The installed Zenmuse X3 camera has a sensor of 1/2.3", with a resolution of 12 megapixel (4096x2160 pixels, 6.17 × 4.55 mm, Pixel Size of 1.56 Micron), a focal length of 4 mm and a Field of View – FOV 94°. The images were acquired through two different modalities: firstly, 106 nadir images were acquired with an automatic double–grid flight plan at a relative altitude of 25 m from the castle's inner forecourt, taking into account an overlap and a sidelap of 80% and 60% respectively. Subsequently, in manual mode, 950 oblique images with different inclinations (30°–60°) were acquired, with the main objective to reconstruct the external and internal facades of the castle. The GSD, from the calculated data available, has been estimated on average considering also the oblique images at 1.3 cm/px, while considering only the nadiral images the GSD is about 1 cm/px. To support the photogrammetric project, 10 Ground Control Points (GCPs) were measured to georeference and assess the accuracy of the generated 3D model and orthophotos. The GCPs were materialized on the ground, using photogrammetric targets (30 × 30 cm) and topographic nails. The GNSS survey refers to the Italian geodetic and cartographic system UTM/ETRF00 and was used the technique network Real Time Kinematic (nRTK). The instrumentation used to measure each target consists of an antenna with a built–in receiver of the Geomax Zenith 25. The accuracy obtained in planimetry is, on average, subcentimetric, while it is around 2.5 cm in altimetry.

Developed Methodology and Quality Features

In order to generate a 3D model of the surveyed area, the Agisoft Metashape software was used. The following parameters have been set to process the point cloud: in the 'Align Photos' stage, accuracy = High (original image), while the calculation of Keypoints and TPs have been programmed as unlimited. The professional version of Agisoft Metashape uses Python 3 as scripting engine and has therefore better interfaces for the purposes of extracting the very inherent reconstruction accuracy parameters that we wanted to export. The following quality features were examined in detail.

- Reprojection Error: the geometric error, corresponding to the image distance between the projected point and the measured point [James 2017, pp. 51-66], is defined as Reprojection Error (RE). It is used to measure how accurately an estimated 3D point recreates the true projection of the point. The frequency distribution of the REs that better fit the data was analysed using Matlab (i.e. the Statistics toolbox). The distribution was used to exclude the external values, that are considered outliers at a selected experimental threshold. The algorithm implemented in the Python environment has been used to remove the 3D point above the threshold of the statistical significance coefficient (α).
- Angle between homologous points and Average distance: by estimating the angle between the two projection lines (called the 'intersection angle'), the Base/Height ratio (one of the parameters that have the greatest impact on the accuracy of the photogrammetric project [Kraus 2007]) is analysed. The photogrammetry software used does not give the value of this angle in the output, so we implemented a Python algorithm. The intersection angle calculation was executed using all the image pairs that contain the i–th TP; once the intersection angle for each pair had been calculated, it was possible to finally determine the average intersection angle between the n images that contain the point, removing the extreme values. Using the number of images and distances already calculated, the average distance between the i–th TP and the n images, was calculated. Finally, with each Tie Point extracted, the proposed method associates the average distance and the average angle value obtained. The whole process is implemented in Python.
- Image redundancy: this parameter is the number of photogrammetric shots implemented within the SfM process, for the reconstruction of the i–th TP in 3D space. With the same other parameters of photogrammetric accuracy, it is assumed that as the image redundancy increases, the metric quality of the TP point cloud improves.
- SOM – Self–organizing map [Kohonen 2001]: is an artificial neural network machine learning technique [Teruggi 2020, pp. 1-27] usually used for visualization and analysis of high–dimensional data. Moreover, SOM is used for data clustering. Self–organizing maps can be combined with dimensionality reduction methods as multi–dimensional scaling [Kurasova 2011, pp. 115-134]. The number of clusters to be brought into the accuracy analysis is extracted from the graphical representation of the dendrogram. A dendrogram (in first page) is a diagram representing a tree that shows the hierarchical relationship between object and used to visualise the similarity in the clustering process. In clustering techniques, the dendrogram is used to provide a graphic representation.

Analysis of Individual Accuracy Parameters

A very noisy standard portion, 50 cm wide, containing vertical walls and the inner yard, was analysed for the purpose of the study. The first parameter considered is RE. The Weibull distribution is the one best–fitting the interpolated data, therefore it was chosen to estimate the characteristic factors of the distribution. The distribution study was used to determine the threshold values, in order to remove the points with associated RE values above the estimated threshold values, more specifically those above the 99, 95, 90 percentiles.

It is possible to observe (fig. 1) how the filtering of the point cloud by analysing the RE and the statistical approach does not generate a good degree of filtering for the section under consideration; in fact, the procedure removes some spots mostly scattered, but it does not lead to great advantages in noise reduction. However, most of the isolated points were not filtered out.

A better result for noise reduction is obtained by filtering the point cloud according to the average angle of intersection, calculated for each Tie–Point, and then analysing the acquisition geometry.
Excluding small average angles of intersection, we have obtained surfaces that are much more realistic and less noisy. Pushing the filter too much, setting high angle values as threshold, compromises the amount of data necessary for the representation; in fact, by setting an average angle over 20° as a threshold, large quantities of points belonging to the vertical walls are removed (fig. 1).
As for the parameter of the average distance between the i–th camera and the TPi, it is a parameter that does not affect the noise. It was also considered to take into account the density of the point cloud: high distances do not allow high GSDs, and therefore not very dense point clouds and cloud sections.

SOM Analysis and Conclusion

It was decided to experiment with a SOM method in order to take into account not only a single accuracy parameter but all the measured parameters at the same time. Using the Matlab Neural Network Clustering App, 4 values was used as input, which were the RE, number of images, average angle and average distance. The SOM Layer loaded with an 8x8 network and 100 epochs. The graphical representation of the dendrogram is used to select the number of clusters for the accuracy analysis. Once the dendrogram is created, 7 categories can be identified. It was decided to divide these 7 categories into 4 groups (fig. 2): 3 accuracy categories (High, Medium and Low) and a noise category. In order to reorganize the clustering of these accuracy levels, we analysed the average angle, the parameters of the maximum and minimum angles, and the number of cameras.
The established clusters 3 and 4, which have the widest mean angle, maximum angle and minimum angle, are classified in this new classification as the High Class. Cluster 2 has been set as the Medium Class, clusters 1 and 7 as the Low Class, and finally clusters 5 and 6 as the Noise Class, with lower intersection values.
Analysing the cluster of the point cloud we overlapped (fig. 2) the 'High Layer Accuracy' containing the highest angle intersection with the 'Noise Cluster' containing the lowest value. It can be seen that the 'High Layer Accuracy' turns out to be the best fitting point set for vertical walls and ground.
The work shows that filtering the point cloud by evaluating the RE and using a statistical approach individually does not produce good filtering quality; in fact, even with high percentiles, some outliers were still not filtered out. Filtering according to the average intersection

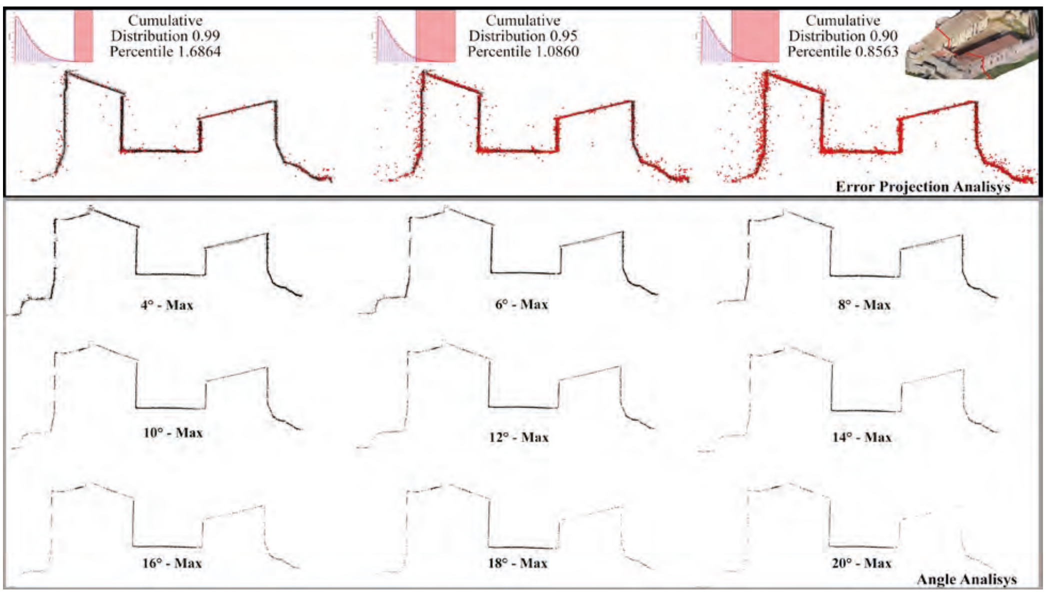

Fig. 1. Single parameter analysis of RE and intersection Angle.

Cluster	Error_Proj (Px)	Num_Img	Angle_min (°)	Angle_max (°)	Angle_Average (°)	Accuracy
1	0,39	53	0,5	28,3	6,5	LOW
2	0,51	72	0,5	28,0	10,2	MEDIUM
3	0,48	120	6,3	64,6	14,4	HIGH
4	0,20	89	7,4	45,1	18,1	
5	0,20	64	0,1	30,1	1,1	NOISE
6	0,26	30	0,1	18,3	2,1	
7	0,36	55	0,2	25,0	6,4	LOW

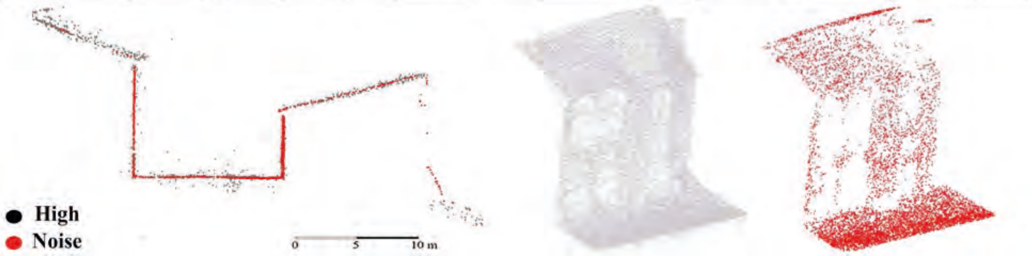

Fig. 2. Clustering and accuracy classes extracted.

angle parameter alone produces a better result for 'noise' reduction. However, filtering through high angles can compromise the data density and cause, as a result, loss of information. With the SOM approach, using all the parameters calculated at the same time and the clustering process, the value of the RE does not change significantly. By analysing the number of images forming the cluster, the greater the number, the greater the noise reduction obtained. Using the cluster angle analysis, we can conclude that the clusters with the highest base–to–height ratio are considered to have the highest noise reduction. Generally, a trend can be defined, i.e. clusters with higher mean angles generate TP sections with less noise. From the analysis above, the parameter that most influences the noise in a TP point cloud is the mean intersection angle. Therefore, we can conclude that the advantages of using AI, in particular SOM, a relatively simple method applicable to point clouds, has allowed a fast clusterization, from which TPs can be selected with different accuracies, depending on the subsequent purposes.

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Authors
Marco Limongiello, Dept. of Civil Engineering (DICIV), University of Salerno, mlimongiello@unisa.it
Lucas Matias Gujski, Dept. of Civil Engineering (DICIV), University of Salerno, lgujski@unisa.it

 Isbn 9788835125280

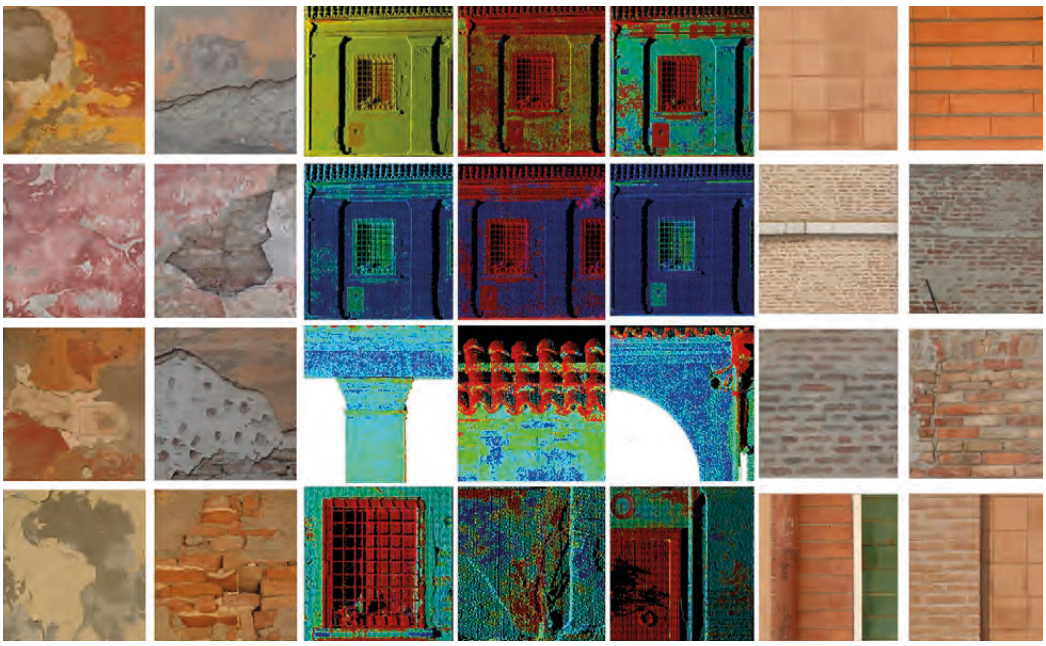
From AI to H–BIM: New Interpretative Scenarios in Data Processing

Federica Maietti
Marco Medici
Ernesto Iadanza

Abstract

The paper results from preliminary research experiences focused on the use of Artificial Intelligence as a tool for processing the large amount of data that can be obtained from digitisation processes applied to the Architectural Heritage. The new interpretative scenarios will be outlined starting, on one hand, from a series of consolidated experiences in the field of three–dimensional survey, modelling and semantic enrichment, and, on the other, from the use of Augmented Reality tools for the fruition of the Heritage itself.
The research aims to further investigate the great potential of processing point cloud models using Artificial Intelligence, to extrapolate, from the digitized data, information levels that go beyond shapes, offering better integration within the Building Information Modeling environment.

Keywords
cultural heritage, point cloud, artificial intelligence, H–BIM, data management.



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Research Scenario

Today's increasingly fast digital surveying tools boost the speed of scanning, but also the amount of data captured. This trend is leading to the development of research avenues in which Artificial Intelligence (AI) is aimed at the segmentation and discretization of data, mainly, but not only, for the recognition of shapes (object detection) and structures [Grilli, Menna, Remondino 2017]. This procedure is triggering a debate, still unresolved, that involves the interpretative aspects of the uniqueness that characterises Cultural Heritage, while the need to trace specific directions emerges more and more.
The research therefore aims to further investigate the great potential of processing point cloud models using AI towards data integration in Building Information Modeling (BIM) environment applied to Heritage.
The definition of a methodology able to automatically recognise specific characteristics from 3D point clouds can lead to the definition of new data sets, aimed at documentation, conservation and restoration, which can enrich BIM models, also thanks to a now necessary inclusion of advanced features in the Industry Foundation Classes (IFC) standard through new and shared Property Sets.
The integration of advanced surveying techniques, Machine Learning (ML) and Deep Learning (DL) in new standards for Heritage information modelling (H–BIM) can have a great impact on the process of documentation, representation, analysis and interpretation of Heritage [Bienvenido–Huertas et al. 2019], creating new representation levels and application scenarios in Heritage management, conservation and restoration.
This research scenario is strongly connected to an additional data management level, related to the application of Augmented Reality tools aimed at 'onsite' data exploitation. A series of experiments were carried out in order to create semantically enriched digital models in BIM environment within an open standard web platform [1]. Data access to the platform via Augmented Reality applications allows Heritage fruition, analysis, monitoring and assessment of Heritage buildings also for conservative purposes.
In this direction, the research includes the use of semi–automatically processed data, related to the state of conservation and technical assessment for asset management, maintenance and decision–making purposes by using mobile devices.

Digital Data Processing for Heritage Conservation

The need to document Cultural Heritage – characterized by uniqueness and complexity – has led to an increasingly widespread use of 3D surveying technologies. These technologies are able to produce very accurate models in a very short time. While, during the on–site survey, the advantages of speed and metric accuracy are evident, the processing of these data can be very time–consuming and complex. Today, the trend is to produce even faster and more robotic instruments (mobile devices) [Gallozzi, Senatore, Strollo 2019] that make it possible to scan (especially indoor environments) in a single shot. This produces an increase in scanning speed, but also a further increase in the amount of surveyed data. This course is leading to the development of a whole Artificial Intelligence line of research aimed at segmenting and discretizing data.
A further layer to be added to this framework is related to digital data representation and management. BIM is considered today the latest frontier of three–dimensional architectural representation, design and management of digital data, where interoperability [Osello et. al. 2015] is one of the central attributes. BIM software applications are growing rapidly and they are also becoming increasingly essential in conservation and restoration applications [Chiabrando, Lo Turco, Rinaudo 2017], thanks to their ability to integrate different information and features in relation to the model geometric shapes [Apollonio, Gaiani, Sun 2017]. However, the IFC, the interoperable standard for BIM, currently lacks in providing a solution for managing the preservation of the Architectural Heritage. Moreover, unlike geometric characteristics [Murtiyoso, Grussenmeyer 2019], an automatic process does not uniquely determine surface features. They become consistent and significant only if critically inter-

preted. Therefore, only if performed with a systematic and well–documented methodology, surface specification analysis can allow a completely non–invasive and strongly helpful support for condition assessment (fig. 1).
Currently, the interpretation of this data and its visual representation as a mapping of the state of conservation requires a manual or semi–automatic and rather lengthy process.

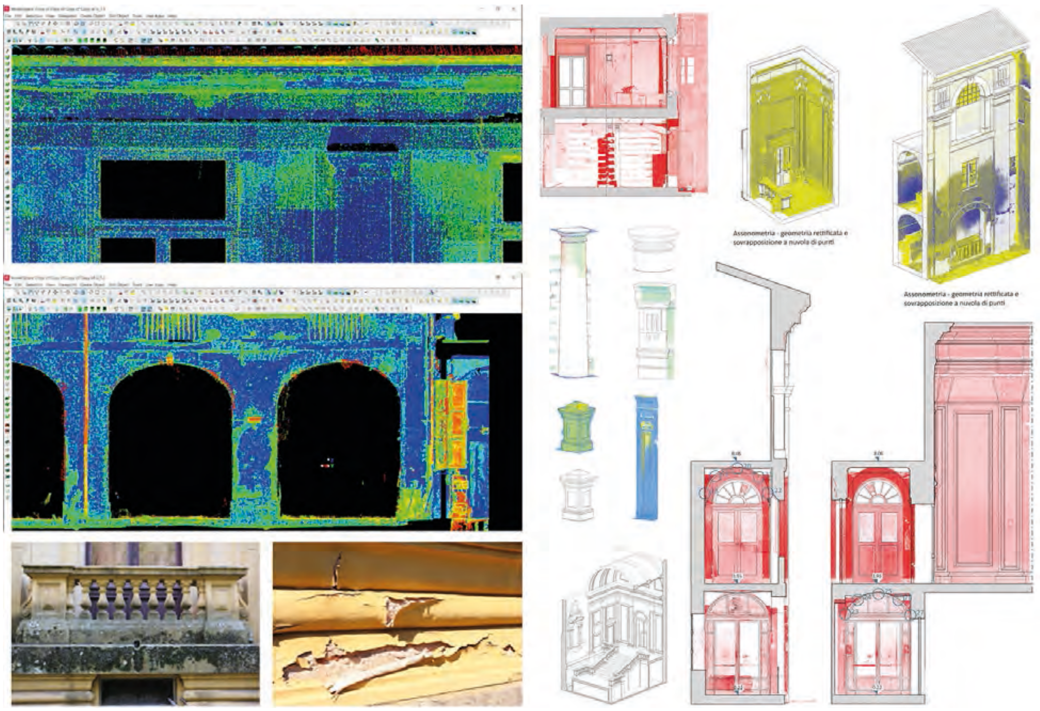

Fig. 1. Analysis of surface specifications by means of point cloud processing and data management in BIM environment.

Even if the concept of setting up automatic procedures and automatisms is very tricky in the field of cultural Heritage (where each building is unique and requires case by case assessments), AI technologies will be more and more necessary since the elaboration of huge amount of data is one of the most important tasks in the digital era [Janković 2020]. These processes can allow – starting from a massive set of data – to explore new forms of discretization and classification. From a single historical building or heritage site, it is possible to extract a huge amount of data that need AI, Machine Learning (ML) and Deep Learning (DL) processes to be analysed and compared. By using point clouds obtained by the 3D survey of a historic building, it is possible to process specific set of points (e.g. related to a certain surface) and to visualize specific surface features [Grilli, Özdemir, Remondino 2019]. AI, ML and DL can make this process faster and more effective [Malinverni et. al. 2019]. Of course, several parameters need to be assessed before the process starts. This procedure can be integrated by exploiting these additional layers of information derived from data capturing procedures for automatically populating the H–BIM model, a research field where there is large room for innovation [López et. al. 2018]. The definition of an extended data schema including information from the restoration discipline, reflecting a shared vision and approach.

From Artificial Intelligence to H–BIM

According to the research scenario about digital data processing for Heritage conservation previously outlined, the research aims to establish a new process of point cloud analysis by applying AI, ML and DL processes, generating interpretative algorithms allowing the segmentation and classification of large amounts of data, in order to outline and describe historical surface specifications. This leads to a methodological procedure as a connection between AI and the automatic recognition of surface specifications to the BIM model, allowing the creation of a new data schema for restoration, including in the IFC standard the detailed documentation of the state of conservation directly extracted from the 3D point cloud by the application of the interpretative algorithms. Such properties will be included into the IFC by the creation of a new set of 'labels' able to describe different data and information related to Heritage buildings within the BIM process. Specifically, the process (fig. 2) involves the selection of databases, the identification of features or properties to be processed through automatic recognition, data processing to identify the algorithm capable of recognizing specific properties, the extrapolation of datasets according to homogeneous features, implementation of new datasets in the BIM environment, and the definition of new IFC 'translators'. The careful selection of interpretation criteria and parameters will be an essential part of the workflow described above.

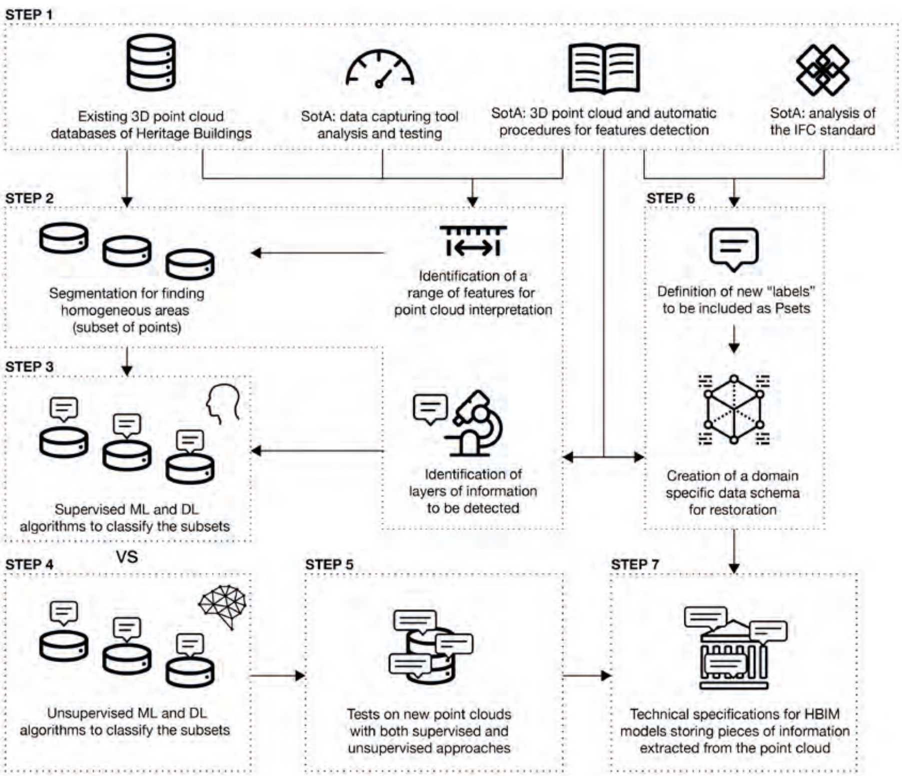

Fig. 2. Graphical schema summarizing the overall process.

This overall process is closely linked with the development of semantic models, beginning with the increasingly advanced identification of features to be incorporated into the BIM models, thanks to Artificial Intelligence. Via Virtual Reality applications, these models can be the foundation for advanced explorations, by leveraging a collection of features relevant to the state of conservation, materials, previous initiatives, technological documentation, directly on–site.

Conclusion

The outlined methodology is the first step in a starting research process, which requires consolidating the described procedures through a number of data sets. Anyway, the project results may have impacts by reaching interesting improvements in some challenging steps of Heritage digitization and data processing for conservation and restoration.
The state of the art outlined on the basis of national and international research related to the application of AI to Cultural Heritage shows indeed an articulated panorama composed of image classification algorithms, point cloud segmentation and representation models able to estimate levels of intervention on historical buildings. However, there is large room for experimentation and many unsolved issues that make the scenario still open and require that multiple levels of knowledge of the Heritage derived from digital languages and tools find a common ground.

At European level, several projects and initiatives are developing the use of BIM for regeneration, but there is still room for progress in the field of application to cultural Heritage. Through the described methodology, geometries and shapes can be integrated with different information regarding materials, state of conservation, historical documentation, previous restoration works, etc.
AI can lead to the development of new, increasingly targeted segmentation algorithms, also to trigger new uses and re–uses of digitised Heritage.
Future research scenarios foresee an integration of Computer Vision and Augmented Reality in the process, for 'onsite' applications, exploiting the data extrapolated through the described procedure, for the enhancement and management of Cultural Heritage, for monitoring or architectural restoration project.

Notes

[1] These experimentations have been developed under the Horizon 2020 project "INCEPTION – Inclusive Cultural Heritage through 3D semantic modeling", funded by the European Commission in 2015 and concluded in 2019 (GA 665220). The project, leaded by the Department of Architecture of the University of Ferrara, focused on semantic modelling of Cultural Heritage buildings using BIM to be managed through the INCEPTION web based platform for advanced deployment and valorisation of enriched 3D models, towards a better knowledge sharing and enhancement of European Heritage.

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Authors

Federica Maietti, Dept. of Architecture, University of Ferrara, INCEPTION Spin–off, federica.maietti@unife.it
Marco Medici, Dept. of Architecture, University of Ferrara, INCEPTION Spin–off, marco.medici@unife.it
Ernesto Iadanza, Dept. of Architecture, University of Ferrara, INCEPTION Spin–off, ernesto.iadanza@unife.it

 Isbn 9788835125280

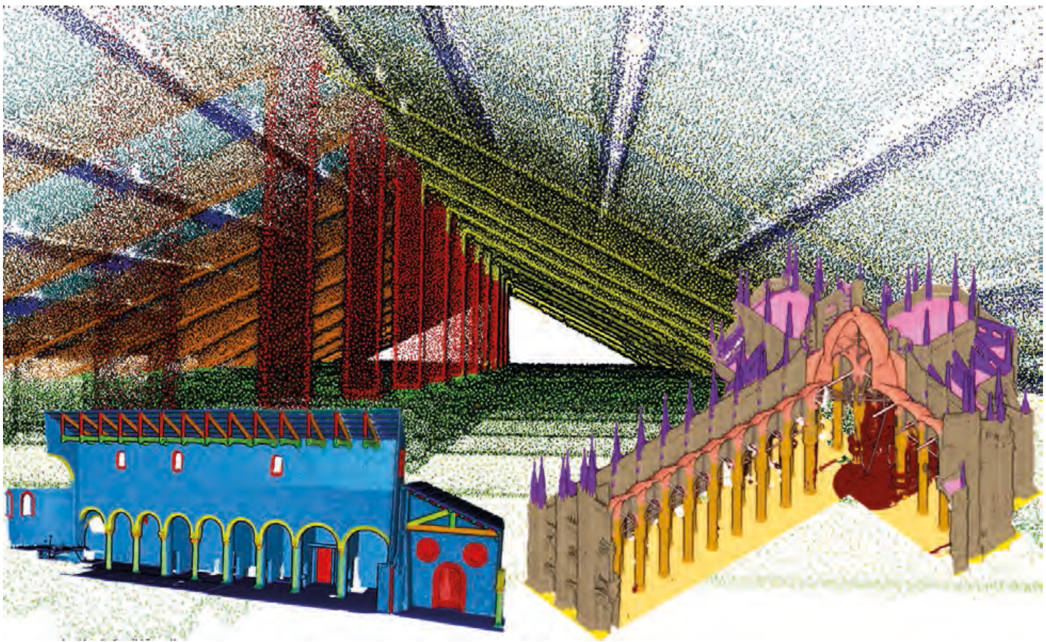
Machine Learning for Cultural Heritage Classification

Michele Russo
Eleonora Grilli
Fabio Remondino
Simone Teruggi
Francesco Fassi

Abstract

Cultural Heritage (CH) assets may be defined as integrated spatial systems composed of interconnected shapes. The classification and organization of geometries within a hierarchical system are functional to their correct interpretation, which is often performed using 3D point clouds. The recurring shapes recognition becomes a crucial activity, nowadays accelerated by Machine Learning (ML) procedures able to associate semantic meaning to geometric data. An interdisciplinary research team [1] has developed a ML supervised approach, tested on the Milan Cathedral and Pomposa Abbey datasets, which presents an innovative multi–level and multi–resolution classification (MLMR) process. The methodology improves the learning activity and optimizes the 3D classification by a hierarchical concept.

Keywords
machine learning, cultural heritage, multi–resolution, hierarchical 3D classification, level of detail.



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Introduction

Cultural Heritage (CH) assets are complex artifacts whose knowledge passes through analyzing an integrated system of forms interconnected by dependence or proximity relationships. The recognition and classification of 3D data become essential to (re)assign a hierarchical and functional meaning to acquired point clouds. The manual classification activity, which is very time–consuming, can be nowadays replaced by an automatic one based on Artificial Intelligence (AI) approaches, such as Machine Learning (ML) or Deep Learning (DL) methods. These AI approaches have many bottlenecks in the CH field, mainly due to the complexity and variability of the shapes, the reliability of the interpreted data, the scalability of the process and, often, the absence of annotated data. In this paper, a supervised ML method applied to CH is introduced and evaluated. It is based on a Multi–Level Multi–Resolution (MLMR) approach, which considers the various geometric details present in the point cloud. Two complex 3D datasets related to Milan Cathedral and Pomposa Abbey are processed to test the developed methodology and demonstrate its flexibility and efficiency with different scenarios.

State of the Art

Several investigations performed to classify (or semantically segment) 3D point clouds in the architectural heritage field using automatic ML and DL methods. Grilli et al. [2018, pp. 1-8] presented a supervised ML approach to transfer classification data from 2D textures to 3D models, whereas Grilli et al. [2020] used a Random Forest (RF) classifier with geometric features to derive architectural classes from point clouds. In the DL domain, Pierdicca et al. [2020] trained the ArCH dataset (http://archdataset.polito.it/) with a Dynamic Graph Convolutional Neural Network (DGCNN) using meaningful features (colour, normals, and HSV), providing promising results. A comparison of ML and DL techniques for the classification of architectural point clouds [Matrone et al. 2020,] shows that similar accuracy results can be achieved. However, ML requires much less time and does not need large 3D datasets in the training phase. For this reason, we hereafter present a supervised ML approach adapted to the different geometric levels of detail and architectural classes.

The Case Studies and Classification Purposes

Two datasets, with different dimensional and morphological characteristics but presenting similar architectural elements, were selected for validating the methodology. The first case study is the Milan Cathedral (fig. 1) which was digitally recorded in the last decade with

Fig. 1. External and internal photos of the Milan Cathedral and Pomposa Abbey, with details of the monumental capitals of the Cathedral and the wooden roofs of the Abbey (authors' images).

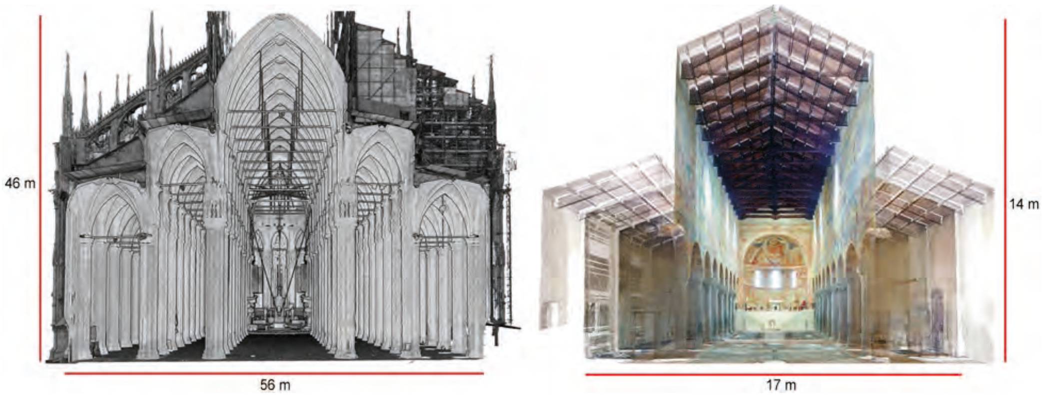

Fig. 2. A view on the point clouds of the two datasets: The Milan Cathedral (left) and the Pomposa Abbey (right).

several integrated acquisition campaigns to generate parametric models [Fassi et al. 2011, pp. 462-487], and define a complete 3D point cloud (fig. 2) at a uniform average resolution of 5 mm [Achille et al. 2020, pp. 331-341]. The classified point cloud may facilitate the 3D data exploration, allowing the integration between archival sources and surveyed data on a web–based BIM–type platform, which can be consulted in situ or remotely. This data organization can also allow multi–scale planning and implementation of conservation and management projects and the quick extraction of 2D representations already classified. The second case study is the Pomposa Abbey (fig. 1) surveyed in 2014 to generate a complete 3D dataset (fig. 2) at a uniform average resolution of 2 cm [Russo et al. 2014, pp. 305-312]. In this scenario, the 3D classification activity can foster access to the system's knowledge, supporting its graphic restitution and the monitoring activities at different scales. Besides, it can facilitate the "quantification" of the building, collecting helpful information for planning a conservation intervention and evaluating the transformations over time.

The Methodological Workflow

The high level of complexity of the case studies highlights two different bottlenecks: on the one hand, the processing of massive datasets cannot be simplified unless losing the level of detail useful in the element recognition. On the other hand, the high number of semantic classes raises the management complexity and reduces their identification accuracy [Teruggi et al. 2020]. An iterative methodology [Grilli et al. 2020] has been developed to overcome these bottlenecks, classifying 3D data in multiple steps according to their information levels (fig. 3). The proposed hierarchical structure is referred to the data density, the morphological and compositional complexity, and the classification purpose. At each level of detail (LOD), the workflow foresees two working steps:
1) The selection of 'covariance features' [Blomey et al. 2014] extracted within specific spherical radii, for the automatic recognition of local geometric characteristics of 3D datum.
2) A small manual annotation to train a Random Forest algorithm [Breiman 2001, pp. 5-32], associating each portion identified by the features to architectural meanings.
The training dataset's selection evaluates the presence of the elements to be classifiied.

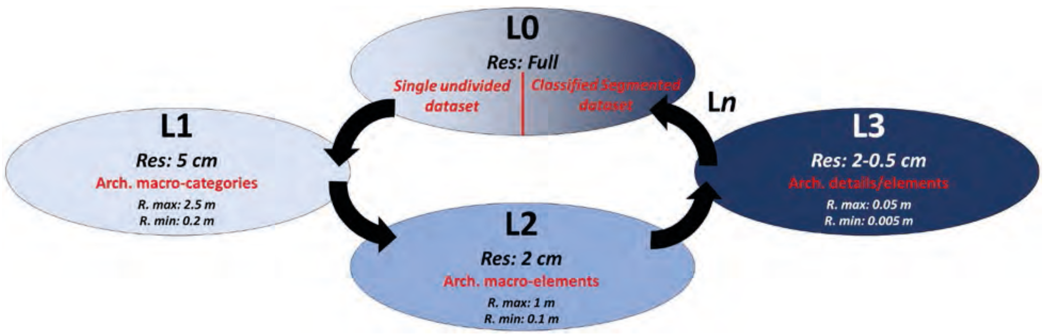

Fig. 3. Schema of the MLMR iterative process.

Experimentation and Results

The classification process refers to the following three–level of details (fig. 4):
– In the first level (L1), a point cloud subsampled at 5 cm, with min/max radius of the features between 20 cm and 2.5 m, was processed, subdividing the churches into architectural macro–categories;
– In the second level (L2), after transferring the L1 classification to the 2 cm resolution point cloud, features extracted with radii between 10 cm and 1 m were used to split the architectural elements into macro–elements;
– In the third level (L3), receiving the L2 subdivision, features with radii of 0.5 and 5 cm were used on the 3D point cloud with a 5 cm density for the Cathedral and 2 cm for the Abbey. This allowed identifying the single architectural monolithic and technologically coherent components.
Both the processing time and the metrics commonly used in ML to define reliability of the results ("Precision," "Recall," and "F1 score" [Goutte et al. 2005, pp. 345-359]), were analyzed to evaluate the classification performance (tab. 1).

Table 1. Timing and metric summary for the two datasets according to the three classification levels. (*) 18 Core Processor; (**) 12 Core Processor.

	Milan Cathedral*			Pomposa Abbey**		
	L1 (5 cm)	L2 (2 cm)	L3 (0.5 cm)	L1 (5 cm)	L2 (2 cm)	L3 (2 cm)
Features computation (min.)	1500			30		
Annotation (min.)	500			60		
Training (sec.)	363	17	142	5	1	4
Classification (sec.)	43	12	174	2.7	1	29
Precision (%)	94.7	99	92	95.3	98	95.8
Recall (%)	95	98	88.5	95.1	97.7	95.7
F1 Score (%)	93.8	99.3	91.8	95.1	97.8	94.6

The achieved results highlight the importance of using point clouds with a level of detail (geometric resolution) and density suitable to support subsampling or backward interpolation processes consistent with identifying architectural elements. Moreover, if the features radii affect only the time in shapes research and the complexity of the architectural connections affects just the classification process, the geometrical density and the processor capacities affect the whole timing workflow (tab. 1). The reported quality metrics show the possibility of obtaining excellent results quickly, identifying even very complex geometric structures.

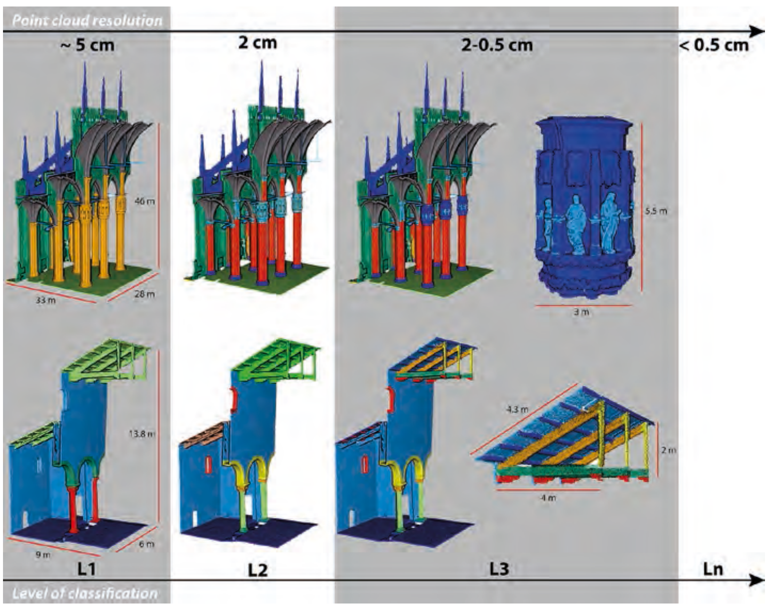

Fig. 4. The classification process of the Cathedral (top) training portion and the Basilica (bottom) according to the resolutions and levels of detail sought by the features.

Conclusions and Future Research

In this paper, a new iterative strategy for supervised automatic ML classification of 3D point clouds of complex Cultural Heritage is presented. Few annotated 3D data were necessary and very detailed semantic segmentation results could be achieved. The cognitive contribution in the supervision phase is crucial in the correct definition of classes and the choice of training and validation sets. These steps are also critical to adapt the general process to the specific case study and different purposes.
In the future, the relationship between classification levels, cloud resolution, and feature search radii will be more investigated, defining a general multi–scenario approach. Besides, the introduction of photogrammetry into the process as a tool to acquire an additional level of detail may be of particular interest. Scan–to–BIM and reality–based modelling from classified data may be specific topics to analyses, supporting the point cloud seg–mentation purposes. A final goal concerns the creation of a classification framework that is more user–friendly for non–experts in the field, broadening its application to different disciplinary areas.

Notes

[1] The presented research is the result of the joint work of five authors. M.R. took care of the Introduction and Conclusions, E.G. prepared the State of the art, the methodological workflow and run the case studies, S.T. supported the methodological workflow and experiments, F.F. and F.R. supervised the work and reviewed the paper. All authors shared the analysis of experiments and results.

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Authors
Michele Russo, Dept of History, Representation and Restoration of Architecture, Sapienza University of Rome, m.russo@uniroma1.it
Eleonora Grilli, 3D Optical Metrology (3DOM) unit, Bruno Kessler Foundation (FBK), grilli@fbk.eu
Fabio Remondino, 3D Optical Metrology (3DOM) unit, Bruno Kessler Foundation (FBK), remondino@fbk.eu
Simone Teruggi, 3DSurveyGroup – ABCLab – Politecnico di Milano, simone.teruggi@polimi.it
Francesco Fassi, 3DSurveyGroup – ABCLab – Politecnico di Milano, francesco.fassi@polimi.it

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Photogrammetric Survey for a Fast Construction of Synthetic Dataset

Andrea Tomalini
Edoardo Pristeri
Letizia Bergamasco

Abstract

In this work we show how Physically Based Rendering (PBR) tools can be used to extend the training image datasets of Machine Learning (ML) algorithms for the recognition of built heritage. In the field of heritage valorization, the combination of Artificial Intelligence (AI) and Augmented Reality (AR) has allowed to recognize built heritage elements with mobile devices, anchoring digital products to the physical environment in real time, thus making the access to information related to real space more intuitive and effective. However, the availability of training data required for these systems is extremely limited and a large–scale image dataset is required to achieve accurate results in image recognition. Manually collecting and annotating images can be very resource and time–consuming. In this contribution we explore the use of PBR tools as a viable alternative to supplement an otherwise inadequate dataset.

Keywords
synthetic dataset, image recognition, visual programming language, physically based render.

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Introduction

In the context of built heritage enhancement, the use of mobile computing technologies for its fruition can revolutionize the user experience [Barsanti et al. 2018; Lo Turco et al. 2019]. AR systems, if properly combined with ML algorithms, can expand the level of knowledge that can be accessed while observing the asset [Spallone et al. 2020]. While it is very easy to imagine the database containing the information associated with an architectural asset, it is less immediate to imagine the query needed to access and explore it. Considering that within the same database very different information is stored: referring to the history, the construction technique, the history of the architect, etc.; one can understand how solutions such as audio tours, information panels, or QR codes are not suitable to answer the subjective curiosity of the user [Andrianaivo et al. 2019]. With the help of a mobile device, starting from the recognition of the object itself, one could connect and reorganize all this information according to the user's preferences [Vayanou et al. 2014].
To enable this kind of navigation, one of the first steps is to ensure that the mobile device can recognize the object in the frame. However, while some disciplines already apply Deep Learning for image recognition [Norouzzadeh et al. 2018; Liu et al. 2020], research is not as flourishing for architectural feature recognition.
This research work proposes a methodology to enrich the training dataset needed to build a software capable of recognizing the built heritage from pictures coming from a mobile device with the help of PBRT tools. Once the architectural artifact has been surveyed, its digital twin can be inserted into a modeling environment and used for the creation of possible views, even improbable ones, expeditiously, taking into account different lighting and meteorological settings which could affect the picture taken from the end user.

Case Study Definition and Data Acquisition

Given the still preliminary stage of the work, the Saracen Tower of Spotorno was chosen as a case study by the research team because of its small size and its position visible from different points of the town. For this specific use case, a three–dimensional model has been useful for the creation of photorealistic rendering used to train a ML algorithm. For this reason, and to optimize working time, it was decided to generate a photogrammetric model by carrying out a free–net adjustment with a subsequent assignment of the model scale by applying the method of least squares over 3 known distances, measured using a metric token (fig. 1). The approach of using elements of known length is a cheap, expeditious and well–established procedure, both in the orientation of the photogrammetric block in industrial applications [Luhmann et al. 2010], and in the survey of archaeological heritage [Nocerino et al. 2013]. The important thing is to correctly size the supports taken as reference – they must be proportionate to the object to be surveyed –, the distance of the images, and the degree of precision and accuracy required by the final model.
The aerial photogrammetric shots were taken using a DJI Mavic Mini drone, equipped with a 1/2.3" CMOS sensor. The dataset was integrated with some images taken from the ground with a Sony Alpha 6000 camera equipped with a 23.5x15.6 mm sensor.

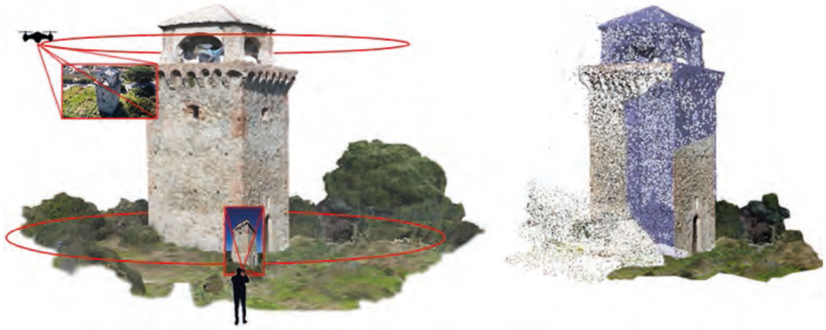

Fig. 1. Conceptual scheme of the survey and construction phases of the textured mesh model.

Despite the non–professional tools, it is now known within the scientific community that the processes of generating point clouds from georeferenced photogrammetric blocks provide excellent results even when the starting data is not a set of images acquired with a calibrated photogrammetric camera. [Cardenal et al. 2004]
The Agisoft Metashape software was used for the 3D model generation operations.
The method used has already been tested and considered appropriate for the survey of elements located in the vicinity of the supports used as references but, despite the cost–effectiveness of the process, even at greater distances the uncertainty is within a few centimeters. [Calantropio et al. 2018]

Dataset Construction Workflow

As previously mentioned, the generation of the 3D model, starting from aerial and ground photos, was carried out using the Agisoft Metashape software. Since the final aim was to produce photorealistic renderings in a fast way, it was fundamental to optimize the mesh, firstly, to reduce the calculation time, secondly, to achieve a representation without gaps, without visible polygon edges and with a more homogeneous appearance. A dense cloud of 5,198,304 points was used as input for the mesh calculation, resulting in a mesh of 345,280 faces. Then, to decrease the complexity of the geometry, the coplanar faces were merged and the areas surrounding the tower were decimated. The output of this process was a mesh of 219,269 faces.
An algorithm was written within Rhino's Visual Programming Language (VPL) environment to automatically generate the useful photorealistic views from this last textured mesh. Grasshopper was chosen as the programming environment because of its ability to naturally manage complex geometries. Moreover, being integrated within Rhino, it was possible to easily connect it to different PBR rendering engines (Rhino Render and V–Ray).
In the algorithm, three working phases can be identified:
1. The identification of useful views around the case study. A hypothetical circular path was drawn around the tower. Along this path 26 chambers were positioned, 13 at one elevation and 13 at a slightly higher elevation, with the centre of the tower as the intake point.
2. Through the analysis of the epw weather file of the location, the solar path was imported. The months between the summer solstice and the winter solstice were selected, and for each month 5 moments in the day were selected in order to have a render for each possible significant position of the sun.
3. The last step was to automate the rendering procedure of all the views for each chosen moment during the selected months. We have 26 chambers, for each of them 5 positions of the sun were selected for the 6 chosen months for a total of 780 images (size of each image 480*480 px). The images were exported in .png format with the contour of the architectural object. It was decided on a first hypothesis to include as little context as possible and to avoid representing the sky, in order to prevent the ML algorithm that would be trained on this dataset from identifying features on objects or landscape components (clouds, bushes or other) other than the tower.
A first dataset built in this way was generated in about 3 hours. Many of these steps could be further automated, thus reducing the required time. (fig. 2)

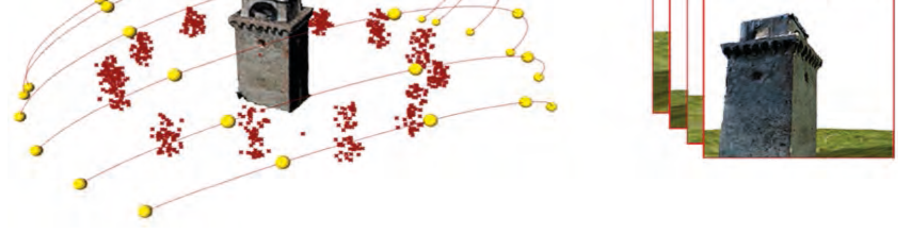

Fig. 2. Selection throughout the year of 30 different lighting conditions and relative camera positions.

Test Classification Pipeline

To test if the data produced by the aforementioned workflow is suitable for training a classification algorithm, a naive image classification pipeline has been created. This has also been useful to identify possible problems with the generated images, such as the issue that will be mentioned in the next paragraph.
The architecture of the pipeline is outlined in Figure 3. The first block is in charge of importing the data as it is. Since in this case we are using a simple binary classifier, we have four different types of data. The two types of data used for training are the pictures generated algorithmically and pictures coming from a public dataset of building facades for the other class. The other two types of pictures used for testing the classifier are real pictures of the tower taken with a camera and other pictures coming from the aforementioned public dataset. The pictures used to train the classifier are then elaborated in the 'Augmentation' and 'Preprocessing' blocks of the script to be ready to be used from the classifier. The test pictures only have to be preprocessed. The classifier is an implementation of a Stochastic Gradient Descent (SGD) [Bottou Leon 2010] classifier which, even if not tuned, allows us to draw some conclusions about whether the data we generated can be useful for image recognition purposes.

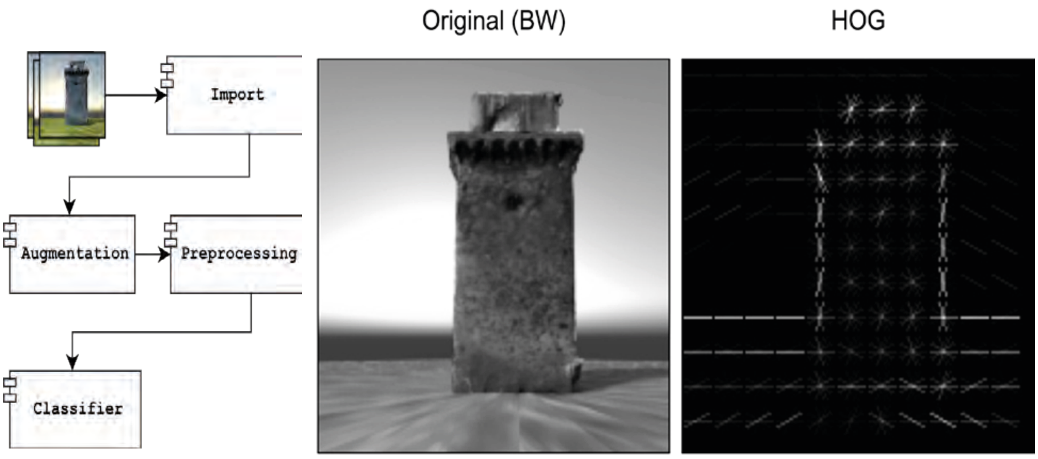

Fig. 3. From the left: Classification pipeline architecture; Two intermediate outputs of the pipeline stages.

Dataset Construction Improvements

After training and testing the classifier on the first dataset, an overfitting problem became immediately apparent. The images, as previously described, were taken with the same camera settings, the same perspective and the tower was always in the center of the picture. As can be seen in Figure 3, to allow the images to be processed by the classifier, they undergo several levels of pre–processing, including the removal of color information. They are then processed by a ML algorithm that calculates the Histogram of Oriented Gradients (HOG), a technique used to select the most interesting features within the image from a software perspective.
If the automatically generated images have a low degree of variability in some regions, which is visible in the HOG data, there is a risk that the classification algorithm will learn to correctly classify only those images with this degree of variability, i.e. the synthetic ones, and misclassify the real images.
To solve this problem, some degree of variability in the relative position of the tower in the image had to be included. The initial VPL algorithm has been modified, spheres have been constructed on the point on which the cameras were initially positioned and for each image the camera has been positioned on a random point belonging to this sphere. A similar solution has also been used for the camera target, with this stratagem the images no longer have the same coordinates and our case study is never in the same position within the image.

Conclusions

Even though it has not been tuned, the classifier scored a ~70% of accuracy in distinguishing images of the tower from images of other buildings.
The benefits of the presented approach versus a more traditional ground survey are clear. In a comparable time we can obtain much more data about the case study allowing to achieve promising results in image recognition with ML algorithms.
With the tested classification algorithm, the background of the rendered 3D object plays an important role as it is processed along with the subject during the pre–processing phase and the resulting information is used during the training of the SGD classifier. The output of the render should in fact have in the background different images which are similar to the true background of the real building, thus adding 'noise' behind the subject and reducing the risk of 'overfitting' the classification model, which would decrease its accuracy.
Including the surrounding scenery into the rendering therefore means providing a more complete context to the subject of the survey. This can be achieved by taking some additional pictures with the drone or by using inexpensive hardware to collect spherical images. This information can be augmented using a 3D rendering engine to include night or dusk settings as well. Moreover this technique also provides the operator a mesh with is useful in the mentioned AR applications.

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Authors
Andrea Tomalini, Dept. of Architecture and Design, Politecnico di Torino, andrea.tomalini@polito.it
Edoardo Pristeri, LINKS Foundation, Leading Innovation & Knowledge for Society, edoardo.pristeri@linksfoundation.com
Letizia Bergamasco, LINKS Foundation, Leading Innovation & Knowledge for Society, letizia.bergamasco@linksfoundation.com

Isbn 9788835125280