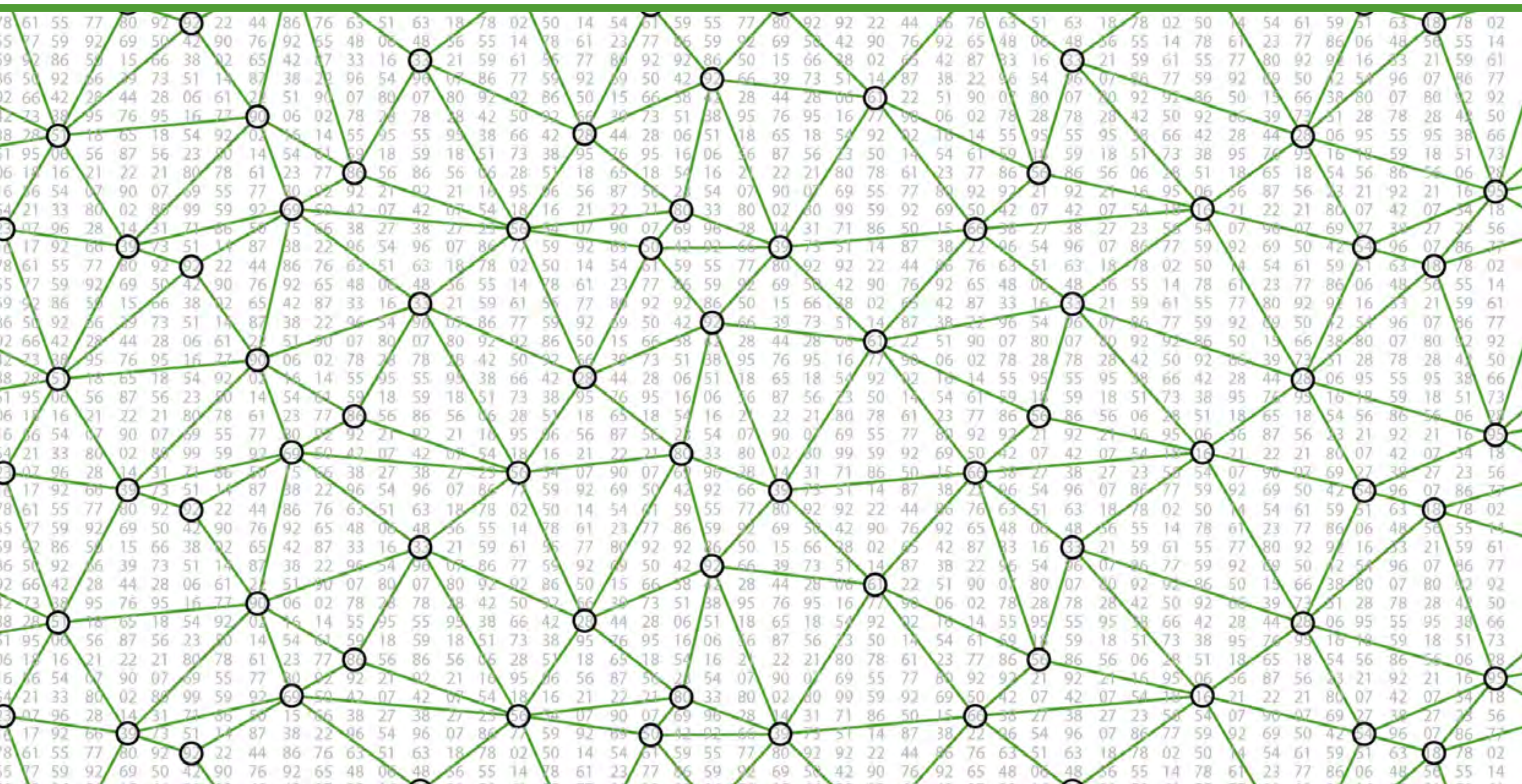
Representation Challenges. New Frontiers of AR and AI Research for Cultural Heritage and Innovative Design.

REPRESENTATION CHALLENGES
New Frontiers of AR and AI Research for Cultural Heritage and Innovative Design

edited by

Andrea Giordano
Michele Russo
Roberta Spallone



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director Francesca Fatta

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Preface

Francesca Fatta

We have reached the second volume of Representation Challenges, a collection of essays developed following the presentation, discussion and peer-review of the proposals exhibited in the REAACH-ID 2021 Symposium, an event organized online by Roberta Spallone, Andrea Giordano and Michele Russo, and already we can make fair juxtapositions with the previous edition.
Both symposia were organized remotely, and this may signify a signal that goes beyond the limitations and obligations dictated by the still festering pandemic; therefore, I would like to mention two international innovations that on the topic of new technologies applied to art and cultural heritage, a few months before REAACH-ID 2021.
On 19 and 20 of June 2021, the first augmented reality art festival conceived by the RMN Grand Palais and Fisheye was held in Paris; this event featured augmented reality artworks in collaboration with Tik Tok, and with a relatively small audience in attendance due to contingency reasons, the number of online views far exceeded one million likes, effectively marking a huge success.
Other news, published by ANSA on 21 of June 2021, concerns China, which has been greatly affected by the isolation given by the Coronavirus. It is expected that between now and 2025 there will be a 77 percent growth in Virtual and Augmented Reality products in this country.
Let's not even mention the great museums and exhibitions advertised all over the world that in recent years have changed the system of use of works of art, such as the Los An-

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geles County Museum of Art, better known as LACMA, which thanks to the collaboration with Snapchat launched an augmented reality campaign for the city of Los Angeles
In the complex field of images, visual communication, and representation, graphic languages have expanded, and augmented reality has become an access tool for a deeper understanding of the existing space and the artifacts contained therein, an additional communication system for the enjoyment of scientific and educational products.
In the last decade, drawing has been able to intercept the stimuli coming from information technology for a synergy between theoretical studies and application systems related to the fields of architecture, the city, and art, today increasingly involved by virtual and augmented realities in all their forms, from monitoring to serious games. Today, horizons are further broadening on the plane of inclusion thanks to the entry of AR and VR for overcoming physical barriers and expanding sensory ones in favor of integration among people, to enhance the diversity of everyone.
In fact, the book shows how much the principle of inclusion is being declined, not only for the world of cultural heritage, always however protagonists in this context, but also in situations increasingly open to the world of psychology and medicine, to alleviate psychic suffering, an area that a few years ago might have seemed distant due to an involvement of representation and technologies for virtual fruition in the relationship between patient and places of care.
This feature is highlighted in this volume with the opening contribution of Pilar Chias, Tomás Abad, and Lucas Fernández-Trapa who, by introducing the term wayfinding in the context of the discussion, relate perceptual factors and orientation systems in hospitals and health centers that can be improved by GPS technology, 3D modeling, and augmented reality.
It does not elude, but establishes an inescapable polarity between natural and artificial intelligence in the fruition of tangible and intangible heritage, where cultural aspects must be considered at the basis of the development of augmented reality projects to transform the fruition of cultural heritage into a more complete experience in view of the ability of researchers to generate 3D scenes, to support the activities of restoration, conservation, maintenance, and preservation of built heritage. The most numerous papers belong precisely to experiences in the architectural, urban and museum fields, including many related to the BIM and H-BIM experience, as well as the increasingly emerging link between AR & AI heritage and archival sources, an area much debated in recent years by the members of the Unione Italiana Disegno.
We are confident that this volume can mark a step forward to further frontiers of graphic representation, open and challenging, capable of combining culture and technology, literature, art and science, in fluid and unconventional places and times. A symposium that demonstrates that technology in the service of representation can also be art, social involvement, as well as innovation.
Special thanks to the tireless organizers and curators, and to all the authors of this volume.

Francesca Fatta
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Representation Challenges: Searching for New Frontiers of AR and AI Research

Andrea Giordano
Michele Russo
Roberta Spallone

We have come to the second collection of essays that originated under the aegis of Representation Challenges and that, by reintroducing the combination of Augmented Reality (AR) and Artificial Intelligence (AI), explores its new frontiers.
The ambitious goal of this second step of the debate triggered during REAACH-ID Symposium 2020 was to go beyond the fundamental census of the research carried out by Representation scholars in Italy and to explore the new boundaries that, after just one year, AR and AI mark in the fields of cultural heritage and innovative design, opening to international studies. This goal has been fully achieved and surprisingly surpassed, thanks to the lymph provided by new proposals and new scholars, which we hope – at least in a small part – to have contributed to fuel and stimulate.
One of the advantages of the structure of REAACH-ID Symposium is that the research topics proposed during the two-day meeting are discussed and refereed by the members of the scientific committee and the committee of reviewers, who provide guidelines and stimuli for ongoing research and ask for clarifications and insights concerning those already completed. The volume of essays presented here is the outcome of the debate and enrichment that the research has received because of this process. For this reason and as the cutting-edge topics addressed require, the outcomes published here result as up to date as possible.
The international Symposium took place online on 12 and 13 October 2021, managed by the Zoom platform of the University of Padua.

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The related abstracts were peer-reviewed and divided into 38 oral and 25 video presentations. This division wanted to preserve the duration of the event (two days) giving to everyone the opportunity to present their research. The sessions were introduced by the Keynotes lectures: Pilar Chías (University of Alcalá), Tomás Abad (University of Alcalá), Lucas Fernández-Trapa (Hochschule Koblenz), Roberto D'Autilia (Università degli Studi Rome Tre), Giuseppina Padeletti (CNR-ISMN), Patrizia Grifoni (CNR-IRPPS), Francesca Matrone (Politecnico di Torino), Camilla Pezzica (Cardiff University), Gabriella Caroti (Università di Pisa), Andrea Piemonte (Università di Pisa), Federico Capriuoli (ACAS 3D Soluzioni Digitali - Università di Pisa), Marco Cisaria (ACAS 3D Soluzioni Digitali - Università di Pisa), Violette Abergel (MAP Laboratory - Lyon - Marseille). 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

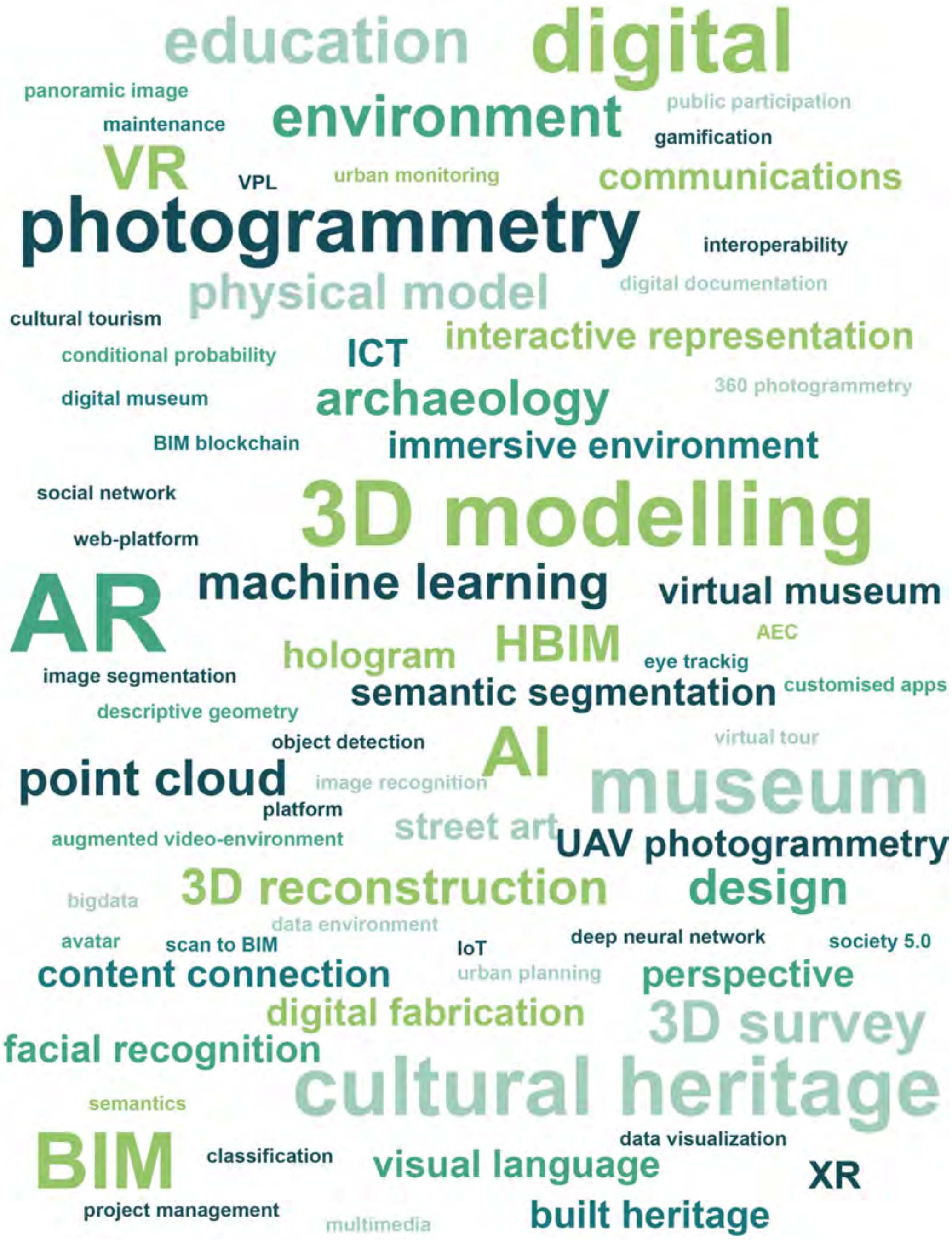

Fig. 1. Word clouds of the book keywords.

were uploaded on the same channel, available to all registered participants for the event.
A demo session collected videos with demonstrations of the experiments conducted on a continuous loop.
From the initial 63 proposals, there are 49 research papers selected and presented in the current volume, with a total number of 148 authors. There is also the presence among the authors of figures not from academia but industry and museums. In addition to the 49 essays, there are 5 keynotes reports, the preface by Francesca Fatta, and the present introductory essay by the editors of the book.
Following the double-blind peer-review of the final papers, the contributions were classified according to five macro-groups: AR&AI heritage routes and archival sources, AR&AI classification and 3D analysis, AR&AI museum heritage, AR&AI building information modelling and monitoring, and AR&AI education and shape representation.
We feel it is relevant to note that, many of the issues addressed in the essays in this volume, developed in the early months of the current year, 2022, correspond to those listed in the final report "Study on quality in 3D digitization of tangible cultural heritage: mapping parameters, formats, standards, benchmarks, methodologies, and guidelines" (VIGIE-2020-654; https://digital-strategy.ec.europa.eu/en/library/study-quality-3d-digitisation-tangible-cultural-heritage), financed by the European Commission, Directorate-General of Communications Networks, Content & Technology. This report, published in April 2022, is the outcome of research conducted by the consortium formed by one tenderer, the Cyprus University of Technology (CUT) and a group of expert subcontractors. This project deals with a field of interest, i.e., the movable and immovable tangible cultural heritage, circumscribed from that proposed by our initiative (which also ranges over intangible heritage and project monitoring and management). Vice-versa, VIGIE-2020-654 makes a broad exploration of heritage digitization, including the concepts of complexity and quality, with a focus on standards and formats, but without neglecting to broaden the look at 3D digitization technologies to the world of Architecture, Engineering & Construction (AEC). In the last section of the report, devoted to the "Forecast Impact of Future Technological Advances", individual points of attention in convergence with the REAACH-ID Symposium topics are, among others: Extended Reality (AR, VR, MR), Metaverse, 5G and the Continued Advancement of Mobile Technologies, BIM, HBIM, HHBIM, Digital Twin, Artificial Intelligence/Machine Learning, and Blockchain Technologies.
The analysis of the keywords chosen by the authors of this volume to represent the content of their research brings out the expected interests concerning digital technologies, primarily AR and AI, as central themes of the call, and their relationships with digital acquisition methodologies (photogrammetry and UAV photogrammetry), of interpretive and informative visualization (BIM, H-BIM, 3D modelling, VPL, digital fabrication, and mapping), of visual communication (VR, immersive environment, interactive representation, and hologram). In addition, several application areas appear (cultural heritage, museum, education, archaeology, street art, urban, built heritage, and virtual museum), and practices related to AI, machine learning and semantic segmentation.
Still other terms, at present mentioned with less intensity, seem likely to foreshadow new challenges of representation, opening up new areas of research and application.

AR&AI Heritage Routes and Archival Sources

This theme is central to the Representation discipline. The great potential of immersive and interactive visualization methods to promote understanding and reading of the existing emerges in the field. The research area develops different approaches according to the scale of application. At the urban scale, Barbara Piga, Gabriele Stancato Marco Boffi & Nicola Rainisio propose state of the art on web-based and mobile applications for collaborative processes in urban planning. The research highlights how two-dimensional representations and non-immersive visualization modes characterize such participatory processes. Remaining in the urban sphere, Ornella Zerlenga, Rosina Iaderosa, Marco Cataffo,

Gabriele Del Vecchio & Vincenzo Cirillo propose a series of reflections on the relevance of smart glasses for the tourist-cultural sphere. They highlight how such devices can be a resource for disseminating and "augmented" enhancement of diffuse cultural heritage.
At the architectural scale, it is interesting to mention two other types of research focused on using AR/VR technologies to represent architectures that no longer exist or have never been built. In the first case, Fabrizio Natta & Michele Ambrosio present a reconstructive digital modeling and AR visualization of the hall of the First Italian Parliament in the courtyard of Palazzo Carignano in Turin, which now no longer exists. The study starts by interpreting documents, archival drawings, and historical studies. These sources are also essential for the second project, proposed by Eric Genevois, Lorenzo Merlo & Cosimo Monteleone. It is devoted to the virtual reconstruction of the never realized "Accademia del Disegno" in Venice by Filippo Farsetti. The primary purpose is to give the palace new "digital" life, promoting and disseminating Venice's artistic and architectural heritage. Moving from the main urban architectures to the minority ones, Giorgio Verdiani, Ylenia Ricci, Andrea Pasquali, & Pablo Rodriguez-Navarro propose an AR-based system to make the traces of these architectures more evident and accessible in the center of Florence. Their research proposes exploring the historic Florentine center that recalls this secondary connective and cultural fabric, crucial for understanding the entire architectural-urban system. Staying on the topic of minority architecture, Sara Morena, Angelo Lorusso & Caterina Garbiella Guida's contribution addresses the issue of the protection and enhancement of lesser-known heritage. Specifically, a tower of the coastal defense system is explored, showing how technologies and the significant development of digitization contribute positively to the accessibility and visibility of this type of heritage.
The image recognition topic related to drawings, paintings, and frescoes is particularly relevant in the 2021 edition of REAACH-ID, providing specific information or suggesting cultural routes. Alessandra Pagliano presents a re-edition of the "Augmenting Angri" research, showing the use of AR as a tool for urban art enhancement and local population engagement. The study proposes the interaction of physical murals with overlaid digital content. Besides, Flaminia Cavallari, Elena Ippoliti, Alessandra Meschini & Michele Russo discuss the theme of democratization and physical decay of street artworks as pillars to preserve during the digital representation process. The research, which proposes some AR applications in Rome related to the figure of Anna Magnani, shows how AR allows achieving the delicate balance between real and digital, enhancing both specificities. Greta Attademo also reworks a 2020 research theme, proposing the definition of a geo-coded map of urban paintings and their use in AR on the graphic image of Naples. As in the previous contribution, weaknesses and strengths in using AR are critically highlighted. The city's iconography conveyed through images is close to that of decorative apparatus and frescoes. On this topic, Marinella Arena & Gianluca Lax reworked a 2020 project, developing an AI-based protocol for reconstructing the missing parts of the Byzantine frescoes of the Church of St. Nicholas. The research has the dual purpose of proposing digital restorations and initiating a formal and symbolic analysis of Byzantine iconography for communication to a broad audience. Staying on the topic of image analysis and underlying geometric constructions, Marco Fasolo, Flavia Camagni & Laura Carlevaris propose a way of applying AR for the communication of architectural perspectives. The study analyzes the decorations of the presbytery and the apse of the Church of Sant'Ignazio in Rome by Andrea Pozzo, promoting the understanding of perspective technique and highlighting the effect of spatial expansion on the architectural environment.
A final declination of the topic focuses on museum routes. Paola Puma & Giuseppe Nicastro repurpose the 2020 EMODEM project to interface virtual and physical space and make the museum experience more visitor-centered, interactive and personalized. The study updates the scientific progress of the research. In the same area, Giuseppe D'Acunto & Maddalena Bassani propose a study and enhancement of artifacts preserved at the Archaeological Museum of Padua. The research specifically addresses the problems related to the graphic restitution of the finds and the possible implementation of their communication through digital tools.

AR&AI Classification and 3D Analysis

The automatic or semi-automatic classification of consistent elements, regardless of scale and according to specific semantic orders, remains a challenging area of experimentation. Its importance is mainly related to the possibility of better handling large amounts of 2D/3D data and optimizing the modeling and representation steps. One of the most relevant passages is defined by the Scan-to-BIM process. Devid Campagnolo proposes a critical state of the art on the topic, analyzing the current trends in the automation of this process. The study highlights the most used approaches and methodologies, providing a point of view that helps to understand better future developments.

At the urban scale, two contributions focus on the topic of the landscape. At the theoretical level, Michela Rossi, Sara Conte & Giorgio Buratti analyze the territory as a complex system. It can be represented through AI models highlighting spatial settlement patterns and developing tools to rebalance the human-landscape relationship. On the other side, Andrea Rolando, Domenico D'Uva & Alessandro Scandiffio investigate the segmentation of spatial images for mapping some types of routes in the Lombardy-Molise territory. The research validates a possible complementary and valuable analysis process in territories where thematic geospatial data are unavailable.

At the architectural scale, data optimization becomes essential to address the issue of a virtual representation. Giuseppe Di Gregorio & Francesca Condorelli illustrate the 3DLAB Sicilia project aimed at enhancing some UNESCO sites through the 3D acquisition, modeling, and visualization with VR, AR, and wall VR systems. The theme of visualization is also addressed by Sonia Mollica, who proposes a study on the use, enhancement, and understanding of Sicilian lighthouses. Through AR and AI, a network of connections between semantic and ontological data is shown to facilitate reading these particular architectures, deepening their relationship with the territory.

Specific use of 3D point cloud segmentation and classification application facilitates conservation and restoration processes. In this field, Valeria Croce, Sara Taddeucci, Gabriella Caroti, Andrea Piemonte, Massimiliano Martino & Marco Giorgio Bevilacqua start from the 3D photogrammetric virtual reconstruction of the Church of the Carmine in Pisa. The study proposes an AI-based classification method that allows digital models of the existing architectural heritage to be semi-automatically characterized in terms of material mapping and state of degradation, simplifying the scan-to-BIM process. Remaining in materials mapping, Salvatore Barba, Lucas Matias Gujski & Marco Limongiello present a study to classify geomaterials. They start from image acquisition by UAV and photogrammetric processing. The study presents a supervised classification method based on orthoimage processing, examining is the "Broken Bridge" between the provinces of Avellino and Benevento.

Finally, at the museum level, Andrea Tomalini & Edoardo Pristeri go deep into the classification topic applied to collections of elements to optimize their management, maintenance, and dissemination. The research proposes the construction of specific datasets with low-budget tools and testing algorithms for recognizing and labeling cultural heritage objects.

AR & AI Museum Heritage

In the museum field, as in other places of culture that provide for the on-site enjoyment of works, collections, performances, projections, etc. the very recent period of the Covid19 pandemic, with the consequent reduced mobilities, closures, and access restrictions, has entailed the massive recourse to modes of communication that have tended to be homologated, which have taken the form of virtual tours and video footage of curator-led visits, more rarely in digitization of art-works made available on web-based viewers, immersive and/or interactive experiences of virtually reconstructed spaces and objects.

The large number of contributions – whose subject matter is museum heritage, outdoor and indoor – may suggest that a significant number of scholars in the disciplines of representation have proposed or have been called upon to offer original and innovative solu-

tions in this regard, aimed, conversely, on the one hand, at bringing the public back to the places of art and making them enjoy immersive and interactive experiences based on digital applications, and on the other hand, at proposing immersive, interactive experiences and original digital applications aimed at creating new links between real and virtual spaces.
The work of Fabrizio Agnello, Mirco Cannella & Marco Geraci creates a double link between the Statue of Zeus, an archaeological artefact housed at the Salinas Museum in Palermo, and the archaeological site of Solunto, where it was found. In the pipeline developed by the scholars, digitization of the site and the statue by laser scanning and panoramic photographs processed with structure from motion technology, modelling and markerless AR experience converge.
The research by Paolo Belardi, Valeria Menchetelli, Giovanna Ramaccini & Camilla Sorignani builds a synergy between AI and AR on the delicate topic of the musealization of psychiatric hospitals, with an experiment related to the Santa Margherita hospital in Perugia. Starting from a single photograph of patients, a plug-in for Character Creator based on AI can generate in real time the somatic features for digital avatars. They are actors recounting their lives, reconstructed through archival documentation, within a virtual museum placed on social networks through an Instagram profile. A physical museum, planned to be installed within a disused gallery near the original site of the asylum, makes use of AR for an enriched immersive experience.
The collaboration between the Interdepartmental Research Center Urban/Eco of the University of Naples and the Museo Archeologico Nazionale di Napoli (MANN) is the framework for the proposal by Massimiliano Campi, Valeria Cera, Francesco Cotugno, Antonella di Luggo, Paolo Gulierini, Marco Grazioso, Antonio Origlia & Daniela Palomba aimed at the augmented, interactive and immersive fruition, through AR and VR, of sculptures by Antonio Canova temporarily loaned by the Hermitage Museum in St. Petersburg to the Neapolitan museum.
Immersivity, interactivity and simulation constitute the key features of the intervention by Maria Grazia Cianci, Daniele Calisi, Stefano Botta, Sara Colaceci & Matteo Molinari, who realize a reconstruction of the Pavilion 2B of the former Mattatoio di Testaccio in Rome as a virtual environment for digital exhibitions. To the digitally reconstructed virtual environment are added the different exhibition proposals and in the space, enjoyed in immersive mode, a kind of "augmented virtual reality" is realized.
Fausta Fiorillo, Simone Teruggi & Cecilia Maria Bolognesi explore the possibility of broadening hologram table capabilities of interaction by developing a custom-designed experience to interact with the 3D point cloud coming from the digital survey of the basilica of Santa Maria delle Grazie in Milan. The holographic visualization can help understand and represent the morphologically complex building and its transformations, while, by customizing the hologram table interface, many data can be added, and the point cloud works as an informative model with associated other relevant information.
Isabella Friso & Gabriella Liva, in light of the continuing pandemic situation, propose the implementation of a virtual museum inside Gino Valle's room of Università Iuav di Venezia. It fulfils the functions of research, didactics, and alternative information, without aspiring to replace the real museum, but working alongside it in the revitalization of cultural objectives and contributing to the success of educational action.
Aiming to improve the management of museum buildings and collections, Massimiliano Lo Turco, Andrea Tomalini & Edoardo Pristeri propose the integration of IoT systems and BIM tools through the writing of flexible algorithms in the VPL (Visual Programming Language) environment. The authors set a computer architecture structured on three layers that collect, analyze, classify, and store environmental information. The first layer is a hardware interface (client) that collects the museum's environmental data and transmits it to the server (cloud or edge); the second layer acts as an interface for analyzing the collected data; the third layer stores locally the data processing to provide decision-making tools.
Davide Mezzino presents two experiences developed inside the Museo Egizio di Torino, in which the opportunities of AR technologies to implement the knowledge and dissemination of tangible and intangible aspects of the millennial historical objects preserved in the Mu-

seum are applied. The author discusses the role of digital strategies and, in particular, of AR in museum contexts aimed at preserving cultural identity and collective memory as well as interpreting and communicating their meanings to wide and heterogeneous audiences.
In the research of Margherita Pulcrano & Simona Scandurra XR systems for the use and dissemination of knowledge about the architectural Heritage are applied to areas that are currently inaccessible, i.e., the archaeological area below the Basilica of Santa Restituta. The methodological approach employs AR as a user-friendly tool that, through the involvement of the user in experiences implemented by multimedia content, allows to highlight unexplored aspects of the Heritage. In this way, it is possible to enjoy an otherwise inaccessible space, while maintaining a certain degree of relationship with physical reality.
Francesca Ronco & Rocco Rolli present a project aimed at the realization of accessible exhibition paths including multi-sensorial experiences in situ (tactile paths and AR experiences) in the Museum of Oriental Art in Turin (MAO), in the framework of the agreement between the Department of Architecture and Design of the Politecnico di Torino and the Fondazione Torino Musei, involving also Tactile Vision Onlus, for the enhancement of the MAO's heritage. Six stages of a knowledge path have been identified, including the museum's entrance hall and five artworks, the subjects of the digital survey, reconstructive modelling, prototyping of AR app and digitally fabricated models and replicas.
Alberto Sdegno, Veronica Riavis, Paola Cochelli & Mattia Comelli deal with the virtual reconstruction and virtual reality communication of the Fire Station designed by Zaha Hadid for the Vitra headquarters. In this regard the authors set up an application protocol that goes from the acquisition of graphic, photographic and documentary information of the architecture to be reconstructed, to low poly modelling, to the generation of specific textures, and lighting studies. Then the authors realize an effective immersive experience, allowing maximum freedom of movement and implementing the system with the programming of interactions.
A storytelling project based on AR experiences is at the centre of interest in Luca J. Senatore & Francesca Porfiri research. The first results of the ongoing digitization process of the collection inside the buildings of the Ostia Antica Archaeological Park in Rome, in particular, related to the case study of the Mithraeum of Lucrezio Menandro show how innovative digitization and data optimization technologies are compared with the immense heritage of the Park, animating the exhibition-interactive itinerary, creating digitally usable content through AR, reflecting on the opportunity of these technologies to create new forms of digital storytelling for use and knowledge.
In the same institutional framework, another project applied to the Museum of Oriental Art also proposes its promotion through crowdfunding, through the creation of the tactile replica and production of activating bookmarks of an AR experience, of Lady Yang, an artwork elected as the museum's mascot for 2021. Marco Vitali, Valerio Palma & Francesca Ronco are the authors of the project, which is being developed through SfM surveying, digital modelling, texturing, including philologically reconstructed colours, digital fabrication (via 3D printing for the tactile replica and raster engraving process of the laser printer for the bookmark), AR experience with the programming of a web-app that allows the digital model and related information to be visualized.
An archaeological artifact housed at the Salinas Museum in Palermo, and the archaeological site of Solunto, where it was found. In the pipeline developed by the scholars, digitization of the site and the statue by laser scanning and panoramic photographs processed with structure from motion technology, modeling and markerless AR experience converge.

AR&AI Building Information Modeling and Monitoring

This is another step of our challenge: the book here assembles a collection of essays that demonstrate the application of digital and interoperable procedures to a range of different circumstances. In fact, this methodological approach – to the fields of architectural/engineering and urban heritage and new constructions – has resulted in new forms of

investigation, documentation and understandings as well as innovative approaches to the life cycle of the building also involving public facing and academic outcomes via multimedia visualizations. This compilation of papers serves as a moment to reflect upon the growth of this methodology, especially with regard to the application of emerging technologies.
In these topics, then, we can recognize the paper proposed by Fabrizio Banfi & Chiara Stanga that proposes a process and the advance of HBIM parameters skilled to communicate heterogeneous standards to support the building life cycle, starting from the survey campaign to the restoration and maintenance of the asset. The core is the improving of information sharing about earthquake-damaged buildings such as the San Francesco church in Arquata del Tronto, moving from for different types of users, digital devices and virtual experiences. The contribution of Rachele A. Bernardello, Paolo Borin & Annalisa Tiengo focuses on a procedure to communicate and enhance cultural heritage value. Combining them with digital strategies and methods, the core of the proposal is a methodology that implements BIM (Building Information Modeling) and CDE (Common Data Environment) concepts to build and organize information of paintings through connected databases, typically produced by multiple actors. Daniela De Luca, Matteo Del Giudice, Anna Osello & Francesca Maria Ugliotti propose an interesting research about challenging aspect of the scientific panorama. In fact, their contribution link and decline Augmented Reality and AI for a gradual scale analysis of artefacts contained in a building in an urban context of interest. Then, multi-level information processing system links the three-dimensional matrix with data collection, representation and visualization techniques – according to specific use cases – achieving the assisting communication processes both for the dissemination of knowledge and the accessibility and usability of data. The project presented by Elisabetta Doria, Luca Carcano & Sandro Parrinello propose an automated approach to the registration and monitoring of technological and architectural elements from considerable photography datasets. Starting from UAV photogrammetric close-range acquisitions of the roofs of the center of Bethlehem, the research gears dataset to train Deep Learning models on a Cloud Infrastructure handling model lifecycle from training to deployment, automating periodic operations to assist large scale monitoring and management of the areas, involving diverse teams and municipalities. The contribution of Maria Linda Falcidieno, Maria Elisabetta Ruggiero & Ruggero Torti proposes the experience of a productive partnership between the Architecture and Design Department (University of Genova) and Grandi Navi Veloci. The core is to set the visual perception of customer caring on board, with the issue of communicating data necessary in certain circumstances, such as in the often unspoken request for the reassurance of the user in the face of moments of unease or concern. Through AR, an interesting app configures elements that inform passengers about the protection and safety mechanisms that are not immediately perceptible. Then combining with AI, the app is able to guarantee involvement through the communication of messages tailored to specific situations. Andrea Giordano, Alberto Longhin & Andrea Momolo propose a research about a BIM-AR workflow to ensure the monitoring of the built heritage. Indeed, the application of AR might be an extension of the BIM since it allows during the on-site surveys' phases to add and update punctual information within the BIM model overcoming the traditional survey methods. Therefore, the proposed information models can performance as collaborative tools on behalf of public authorities and stakeholders utilization, achieving a proficient building management, also from a preventive perspective. The stimulating contribution of Valerio Palma, Roberta Spallone, Luca Capozucca, Gianpiero Lops, Giulia Cicone & Roberto Rinauro highlights current opportunities and limits of the the interaction between AR and building information modeling (BIM) technologies fully scalable. In this sense, the study intends to integrate immersive technologies and information modeling for the built space. The core is then the implementation of tools and processes to rapidly recognize the equipment present on telecommunication network sites and access the corresponding components on a digital information model. The output of the first phase of the project is an app prototype for mobile devices capable of showing a 1:1 scale AR representation on-site. The proposal of Fabiana Raco & Marcello Balzani enhances the problematic that there is redundancy,

multiplication, lack of transparency and disaggregation of data and information for the construction industry, with deleterious response in terms of time, cost, and quality of the project life-cycle management. The core of tis paper is the development of a TRL 4-5 ICT application that integrates Building Information Modeling and blockchain technologies, to digitalize procedures in the supply chain that guides better information flow transparency, knowledge-based organizations, and decision-making processes based on explicit ordered data. Colter Wehmeier, Georgios Artopoulos, Federico Mario la Russa & Cettina Santagati propose an impacting contribution centered on the Cantieri Culturali della Zisa, Palermo, part of a co-design workshop called Everyday Experiences and Heritage in South European Cities: Digital Tools and Practises. The proposed research contest is about methods in 3D scanning and augmented reality for public-inclusive architectural programs through rapid survey, accessible design tooling, and immersive visualization outcomes. The research core describes the benefits of pedestrian-operated 3D structure-from-motion survey for historic urban scenarios, implementing a cloud-based augmented reality app modified for accessible proposal creation and visualization.

AR&AI Education and Shape Representation

With the contributions of this section, we have arrived at a time for deepening the academic training and coaching, involving a deeper embracing of digital-media circumstances. Traditional methodologies of architectural and urban history must remain the foundation of digital approaches, becoming part of the new scientific-methodological practice that digital applications offer. An ambitious enterprise – with varying expertise and multi-disciplinary backgrounds – that emerges from all the paper here offered, involving simple models or digital data, but rather creating dynamic interactive and interoperable displays that can show complex / new modes of education / communication. Then, new processes and codes for communicating knowledge-based visualizations have assumed a decidedly important role, proposing the capacity to present a more fully three-dimensional revelation and subsequent analysis of data than traditional publications might offer in certain contexts, also the everyday life. Is the case of the contribution of Raffaele Argiolas, Vincenzo Bagnolo & Andrea Pirinu that shows how Information and communication technology (ICT) are currently a basic part of training and educational activities. The aim is the improvement of an augmented reality application for accessing documentary sources used in the teaching of drawing disciplines in architecture courses at the University of Cagliari, involving students in the deeper study of the Castello district and its architecture, organized as an "access point" to the knowledge. The paper of Giulia Bertola, Alessandro Capalbo, Edoardo Bruno & Michele Bonino reflects on how, in the age of the immaterial, a plastic model is an apparatus still contemporary in the representation with the new digital tools of augmented reality (AR). In this context, the basic of the proposed research is the experimentation of the realization of two static scale models, through Digital Fabrication technologies, aiming to increase the accessibility to knowledge about the architectural project in an exhibition context. The developed methodology allows the user to obtain information about the architectural project not only through the real model but also through static and dynamic virtual models overlaid using the current AR technologies. Michela Ceracchi & Giulia Tarei propose the implementation of an Augmented Reality museum of mathematical-physical models specifically for educational purposes and capable of explaining mathematical and geometric principles. The main feedback is the interactive accessibility of Max Brückner's collection of polyhedra models. The achieved digital twins of the solids facilitate the illustrative contents, with a replica of paper mock-up, thus giving pedagogical importance to the mathematical models otherwise precluded during the exhibition in a showcase or preserved in storerooms due to restricted exhibition space. The proposal of Serena Fumero & Benedetta Frezzotti shows the educational and advertising mission pointed at reaching a wider audience, specifically targeting the youngest visitor's global effort to promote the museum site of the Precettoria of Sant'Antonio di Ranverso, property of the Fondazione

Ordine Mauriziano. This objective is carried out with the didactic experience of Techniques in Visual Arts course at the Libera Accademia d'Arte Novalia. The course develops the potentials offered by augmented reality, both as a way of dissemination the knowledge of the site, also addressing a younger audience with educational content. The interesting contribution of Francisco M. Hidalgo-Sánchez, Gabriel Granado-Castro, Joaquín María Aguilar-Camacho & José Antonio Barrera-Vera describes the first evolving phases of a tool designed to support field-training sessions in topographic survey learning courses, also involving gamified simulator. Then the proposed research experience emphasizes how the mixture of software and hardware under a unified criterion oriented to the virtualization and gamification can significantly improve the learning process of practical land surveying. The paper of Javier Fco. Raposo Grau, Mariasun Salgado de la Rosa, Belén Butragueño Díaz-Guerra & Blanca Raposo Sánchez improves a fascinating experience about the connection between creative processes and artificial intelligence in the field of graphic expression. The authors then underline that this connection have to be intended not only as a substance of technological development but also as a solver of the articulation of logical / rational processes with creative/emotional ones. The experience is based on the teaching methods of drawing at the School of Architecture of Madrid and wishes to explore how these educational strategies allow the development of work habits promoting characteristics that can be used in other environments. Specifically, this experience, the dynamics of collective work between teachers and students has made it possible to establish the relationship between artificial intelligence and creative processes in teaching activities throughout the different phases of learning.

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Keynote Lectures

AR Applications: Wayfinding at Health Centres for Disabled Users

Pilar Chías
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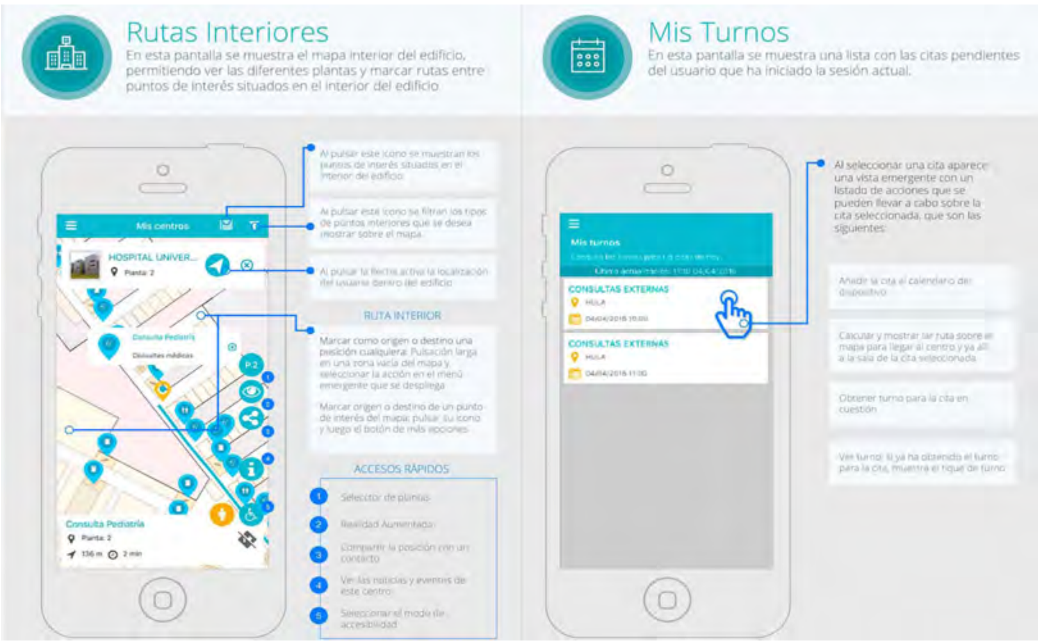
Abstract

The term *wayfinding* describes the processes people go through to find their way round an environment. People's perception of the environment, their ability to orientate themselves spatially, the cognitive and decision-making processes, and the information available, all affect how successfully they find their way. At hospitals and healthcare centres a specific wayfinding strategy is needed. Emerging technologies as computer-based and stand-alone navigation systems tailored to the needs of various types of disabled users. Accordingly, they meet requirements of psychology and human behaviour, and communication technologies. GPS technology, 3D modelling and Augmented Reality (AR) among other, are revolutionising the way people navigate. Such solutions applied to motor and sensorially disabled people, and mentally impaired users become an increasing societal demand in the face of EU integration challenges. The University Hospital Príncipe de Asturias in Alcalá de Henares (Madrid, Spain) is used as a case study.

Keywords
wayfinding, navigation tools, people with disabilities, customised apps.



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Introduction

"Wayfinding is the process of finding routes between pairs of locations and is often used for pre-trip planning. Navigation is the process of finding the current location of a person or object in real time and providing step-by-step directions to reach a destination" [Karimi 2017, p. 2455].
In any publicly-accessed site, people can have problems finding their way. Getting lost at a hospital or healthcare centre is so much a part of daily life, that solving wayfinding problems is a severe problem that creates anxiety and rises stress levels in users.
To develop an inclusive indoor and outdoor navigation system, a wayfinding strategy that covers all possible disabilities is needed. Though signs do play a key role in any wayfinding system, signs alone cannot overcome the wayfinding problems caused by complex site layouts as in hospitals. Moreover, signs are only useful if they are linked to other navigation strategies as pre-visit information and environmental and design factors, such as clearly defined safe pathways, prominent entrances, natural lighting, changes in texture and colour, etc.
This chapter shows some results of the Spanish National Research Project PID2020-118796RB-I00_2020, that is still ongoing. University Hospital Príncipe de Asturias in Alcalá de Henares (HUPA, Madrid, Spain) is used as a case study.
Firstly, we provide a study on the specific needs and requirements of users focusing on the various motor and sensorial disabilities. Secondly, we show some interesting best practice guidelines to produce a more effective wayfinding system, they need to be adapted to each case study and site users after careful evaluation of the current navigation system. Thirdly, 3D modelling and ICT Technologies application to health centre knowledge and management are reviewed and analysed, as well as the pros and cons of current navigation solutions based on GPS technology, and Augmented Reality (AR). Conclusions show how architectural design and communication technologies can affect the user's wellness and recovery if they consider psychology and human behaviour.

State of the Art

We are witnessing a rise of concerns about indoor and outdoor navigation related to public facilities, and particularly to health centres. But literature on related topics is far from being homogeneous. While signage – as a part of the visual identity of public administrations and companies – and motor disabilities are widely discussed, mentally impaired patients' needs are still insufficiently studied despite their increasing prevalence in population [1].
For years, sensorial disabled people other than visual have been neglected for the study of hospital navigation, together with mentally disabled people. Due to this lack of awareness and knowledge, architectural design has been far from promoting self-sufficiency and self-esteem to health centres users.
Precedents for wayfinding and navigation services with reference to architectural design are the human-centered studies by Topo and Kotilainen [Topo, Kotilainen 2009], Marquardt [Marquardt 2011], Brusilovsky [Brusilovsky 2015], Karimi and Hashemi [Karimi, Hasehmi 2015], and Karimi [Karimi 2017] must be stressed, together with the guidelines produced by agencies such as the American Psychiatric Association [APA 2007], the Americans with Disabilities Act [ADA 2010] standards, and the *Health Building Notes* (HBN) and *Health Technical Memoranda* by Department of Health, UK. For the purposes of research project, the following are of particular interest: HBN 03 'Mental health', HBN 05 'Older people', and HBN 08-02 'Dementia-friendly Health and Social Care Environments'. The Spanish Organización Nacional de Ciegos (ONCE), the Spanish Ministerio de Sanidad, Servicios Sociales e Igualdad, and the Real Patronato sobre Discapacidad are promoting numerous initiatives related to universal accessibility and inclusive architecture.
Literature is abundant on 3D modelling and visualisation problems, too. After the pioneering studies in the 1990's, an interesting review can be found in Remondino [Remondino 2003]. Advanced technologies for historical cities visualisation have been summarised and applied by Giordano and Love [Giordano, Love 2018].

From the perspective of Augmented Reality and TIC, some recent applications to the built Heritage must be stressed as those by Giordano and Repola [Giordano, Repola 2016], by Spallone and Palma [Spallone, Palma 2021], among other.
Applications to interactive museums by Fatta, Basetta and Manti [Fatta, Basetta, Manti 2016] can be directly related to hospitals' navigation and 'edutaiment' [2] (Fig. 1).

Mentally and Physically Impaired Users of Health Centres: From Needs to Preferences

To be aware of how accessible the traveling indoor and outdoor environment is, and how people with mental or physical disabilities find their way and navigate is of great importance. Considering the existing standards, the challenge is how to particularise the general guidelines for healthcare environments.
Ontologies focused on wayfinding and navigation activities of disabled people can help, as they reveal their needs and preferences. Consequently, an ontology should be defined for each disability and particular site (Fig. 2).
Moreover, for people with disabilities it is crucial to know in advance whether the health centre to which they need to travel have accessible entrances. Consequently, indoor and outdoor points of interest must be checked to know if they comply with the set of standards. Afterwards models that reflect the wayfinding needs of people with disabilities must be developed.

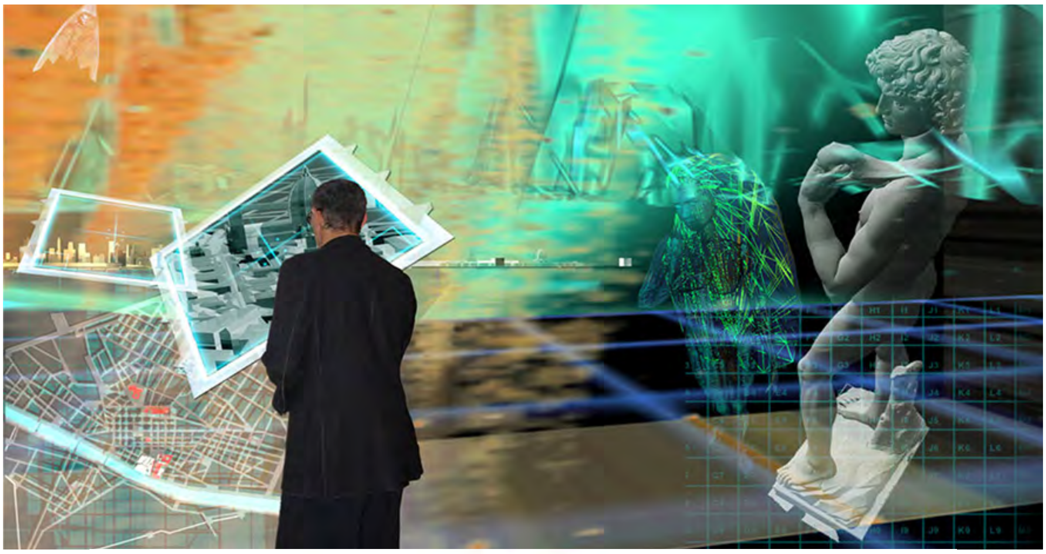


Fig. 1. Franz Fischnaller: City Cluster - From the Renaissance to the Megabite Networking Age [Fatta, Basetta, Manti 2016].

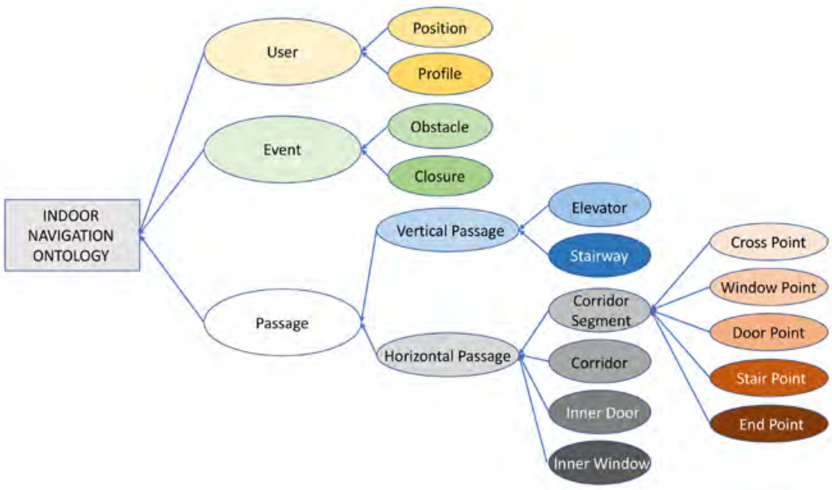


Fig. 2. An ontology for wayfinding and navigation of people with motor and visual disabilities inside the University Hospital Príncipe de Asturias. Ground floor [Chias, Abad 2017].

At the community level, models must address the specific needs of each disability community, while at the individual level the specific preferences of each one.
For example, the challenge is to make dementia-friendly design as a step forward regarding adult mental health unit design.

Best Practice Guidelines for Hospitals' Architectural Design

Health facilities professionals learnt how to embed wayfinding principles into the architecture itself. The solution was no longer hanging more signs that too often confounded the visitors but creating a graphic culture in which handicapped visitors and patients could intuitively navigate while experiencing landmarks and places along the path of journey. As this challenge shifted, the multidisciplinary teams of designers were expected to embrace evidential design, including the new science of wayfinding, and working in collaborative environments.
As a result of this collaborative work, effective wayfinding must be more than just functionality: must be patient-centered and customised. From this perspective the key fundamentals can be summarised in the following points:
1. Wayfinding strategies must show a strong brand identity, providing an ideal platform to communicate the organisation's values and mission to connect with patients on a deeper level.
2. Re-think tradition and tell a story. A meaningful relationship between zones should be created based on the hospital history or prospective (Fig. 3).
3. Truly enhance patients' experience. It supposes more than just direct patients from point A to B: it's a pillar of a great patient experience, turning what can be a frustrating ordeal into a smooth, engaging journey. A more unified experience between all the moving parts – tech, the built environment, staff – is critical to alleviating stress and maximising efficiency.
4. Timeless design for flexibility and consistency.
5. Solicit lots of feedback coming from all sides. Wayfinding in healthcare is supposed to be intuitive – but how can you design it when everyone's intuition and sensitivity are different? Work with the various users and testing were influential on many factors. Prior to a pilot, you need to put yourself in the patient's shoes – literally. Pilot approaches are of great value before rolling out an idea, and must include testing, working with various disabled patients and family focus groups, and then incorporating their feedback to validate processes.
6. Cultural sensitivity becomes essential to reach an inclusive design, universally understandable and culturally acceptable. To make certain a scheme will appeal to diverse populations, it

Fig. 3. Alder Hey Children's Hospital navigation, play and edutainment experience. [Alder Play, Ustwo Games].

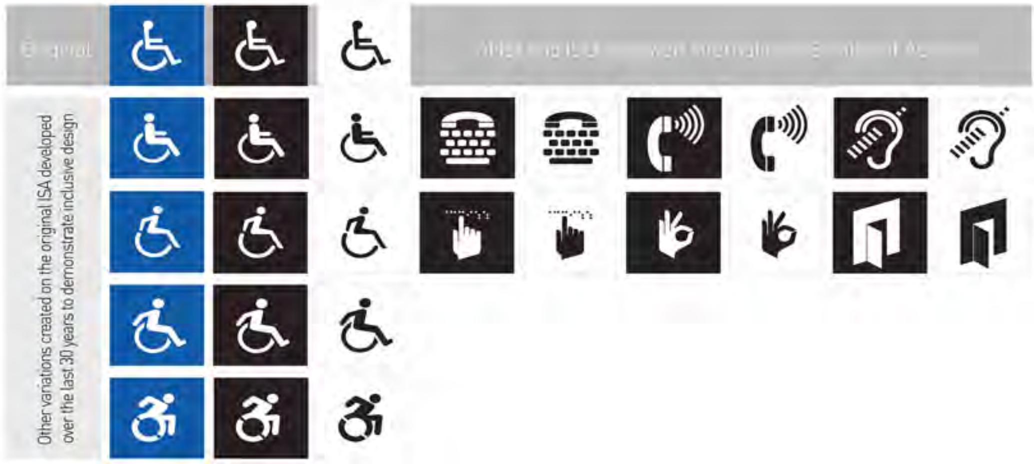


Fig. 4. Accessibility symbols that seek to create experiences that are inclusive, legible, and accessible to all [Hablamos Juntos, SEGD 2010].

is essential to put it through many different filters. Multilingual signage is becoming the standard, but inclusivity extends to those with different types of colour blindness. In the United States, initiatives developed by the partnership between 'Hablamos Juntos' and the Society of Experiential Graphic Design SEGD provide universal symbols and practical solutions to language barriers in health care [Hablamos Juntos, SEGD 2010] (Fig. 4).
7. Make maintenance and updating a priority.
Wayfinding should be addressed in the programmatic phase, when handicapped users can be surveyed. Wayfinding nomenclature can be developed based on a hierarchy of information. For instance, information should be developed that leads from point-to-point rather than confusing visitors with too much information, typical of directional flagpoles and directory floor plans – that cannot be used as unique points of orientation by visually or mentally impaired people, as well as by many elders. Most people can recall a landmark before they can recall a floor plan with a You are here' spot. According to this, walls, furniture, and art can be embedded to be points of orientation.
As it becomes extremely important to design space that could be recalled in a cognitive map, often a mock 'patient journey' has been undertaken. It can be available from a patient's home to the health care facility parking lot and, once there, hospitals should be equipped with interactive kiosks and app utilities that give directions in multiple languages and user-friendly interfaces.
Mapping software can help at every turn, giving designers opportunities to be language-friendly and accessible to the disabled.

3D Modelling and GIS for Health Centre Knowledge and Management

Health centres knowledge and management need the integration of computer vision technologies with wide multiformat databases that include objective and subjective datasets, and must be constantly updated [Chias, Abad 2021, pp. 44-45]. An ontology model defining the interaction between digital databases and Interfaces was previously defined [Palma, Spallone, Vitali 2019].
Consequently, data sources are varied depending on the kind of data. Objective datasets as health care building geometry, dimensions, visible architectural elements and finishings are recorded by means of laser scanning technologies and integrated into a 3D model (Fig. 5). High precision differential GPS sensors were used as location sensors, mainly in outdoor areas at the Hospital.
From scans and GPS datasets we produced the digital base maps of the Hospital for GIS implementation.
Accessible sidewalk networks composed by segments were defined with accessibility attributes and according to topologic relationships. For indoor wayfinding and navigation, the base map contains hallway network on each storey, and connection between stories with accessibility attributes of each hallway segment – as door width, or surface condition. Queries on accessible points of interest – such as entrances – and optimal routes can be answered through GIS.

Fig. 5. 3D model for Augmented Reality of the Paediatric ward, University Hospital Príncipe de Asturias, Alcalá de Henares, Madrid [Chias, Abad 2021].

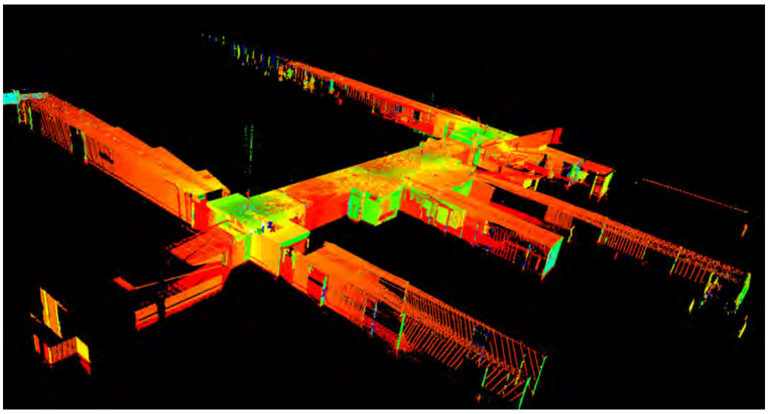
Other objective data collected refer to technical equipment and facilities, indoor traffic flows, scheduling, patients' medical record, pharmacy, etc.
In contrast, subjective data are gathered about handicapped users and accompanying people personal experience during and after a hospital stay, by means of interviews and questionnaires. In this case, materials collected are highly sensitive and privacy protocols must be previously established to safeguard health information. Data sets are structured in multiple layers to progressively extract higher-level features from the raw input by means of machine learning algorithms.
Next step required to customise an app for a mobile platform to develop 3D object recognition and tracking functions, on which AR tools are based. Simultaneous locating and mapping systems (SLAM) [3] based on tailored algorithms are used. Sensors as laser scans and visual features provide details of many points within the study area at the University Hospital Príncipe de Asturias (HUPA), working at the architectural scale. Point clouds were then recognised and compared with the environment surveyed at runtime (Fig. 6).
Consistency and accuracy of positioning data gathered with the GPS sensor proved to be adequate to the research aims.

ITC Technologies and AR-based Solutions for Indoor and Outdoor Navigation

Next stage is to integrate subjective and objective datasets from the various data sources using image recognition functions enabled by Deep Learning (DL). Through image processing, lower layers may identify edges, while higher layers may identify the concepts relevant to navigation purposes.
Wayfinding and navigation systems are customised computer systems – stand-alone systems – that perform all operations without needing remote servers. Two main technologies are being applied to health centres.
On the one hand, the use of beacons or similar technologies to provide indoor GPS' directions exists but is rarely implemented – primarily due to cost, that is a serious disadvantage.
But the most mature and widely deployed wayfinding technology is web-based tools, that allow out-patients to plan their visits ahead of time. Mobile solutions and personalised apps have moved electronic signage to a next level, as smartphones can be used to access the wayfinding website to get visual and aural guidance along their journey. 3D wayfinding tools use mobile-friendly 3D maps to provide point-to-point directions and seamless transitions between multiple floors and across facilities and medical campuses, including audio to engage another sense (Fig. 7).
Alternatively, users of health centres can chart their course from an interactive kiosk in the lobby and download the map to their phone using a QR code. As a step towards highly personalised health care, some stand-alone kiosks have talking avatars or video greeters that facilitate comprehension and give additional information such as walk times. They can also include magnetic stripe readers and bar-code scanners that provide an additional point

Fig. 6. Accumulated registered point cloud from scanner laser. Emergency department, Paediatric ward, University Hospital Príncipe de Asturias, Alcalá de Henares, Madrid [Chias, Abad 2021].

Fig. 7. Patient portal of the University Hospital Fundación Jiménez Díaz, Madrid [Chias, Abad 2021].



of integration. Moreover, they can deliver personalised content and applications such as appointment scheduling, pharmacy check-ins and patient-to-doctor communication.
Among other advantages of mixed navigation systems are the possibility of quick updates and the integration of Media Nav maps including BLE beacons, WIFI, located-based messaging, voice-activated search, and geomagnetic positioning to accurately track a user's location indoors via a 'blue dot'. By using a built-in magnetometer and other smartphone sensors, the magnetic field inside buildings can be used to pinpoint and track users within 90 cm and 1,5 m. These systems improve venue safety, accessibility, and the overall user experience. Moreover, as powerful integrative tools they should address language barriers and solutions that are landmark-based.
In addition, most of the systems can be managed remotely from an internet-enabled device.

Conclusions

Digital wayfinding is making inroads in health care centres but still has a way to go. However, no matter the size of the digital display, the impact also is significantly determined by the quality of the content.
One of the key features associated with digital signage solutions is data collection and management.
Location-based tracking, reporting and analytics give hospitals real-time visibility into the location and status of patients, visitors, vendors, and staff, coupled with visual analytics on historic patient, on visitor and staff workflows.
In particular, the following information on experience of handicapped users has high value: waiting times at different surgeries, transit times for different patient journeys to book appointments, etc.
Obviously, among key best practices the possibility of changing the wayfinding program as often as the health care centre changes, becomes mandatory. However, technology is a friend to younger patients and family members, but it can be also a perceived enemy to older populations, particularly to those who are sight-impaired or mentally handicapped people. This has consequences for elderly populations and major implications for the larger boomer generation that will become the primary user of health care facilities.
But can navigation technologies replace face-to-face contact? Challenges include the potential loss of the personal touch. A front door valet and concierge greeter make visitor feel special and safe, having the opportunity of being emphatic. They can answer questions directly and even walk patients to their destinations within the hospital. Thinking of the consequences of a technology failure, visitors may be confused, frustrated, and perhaps lost, but when wayfinding programs incorporate the human connection, they feel relieved.
Patients and hospital users need navigation support, not natural navigational replacement
As a conclusion, the challenge is to make dementia-friendly design as a step forward with regard to adult mental health unit design.

Notes

[1] The prevalence increases dramatically with age: approximately 5% to 8% of individuals over the age of 65, 15% to 20% of individuals over the age of 75, and 25% to 50% of individuals over the age of 85 years are affected. Source: Eurostat.

[2] Edutainment platforms are working with hospitals to optimize their education strategy and extending it beyond the four walls of the facility, both pre- and post-stay. They are finding new ways to serve as patient's digital personal assistants and engagement tools, playing a complementary role in the interactive patient experience and in data collection.

[3] SLAM is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it. The system requires a previous acquisition of point clouds of the chosen areas at the HUPA.

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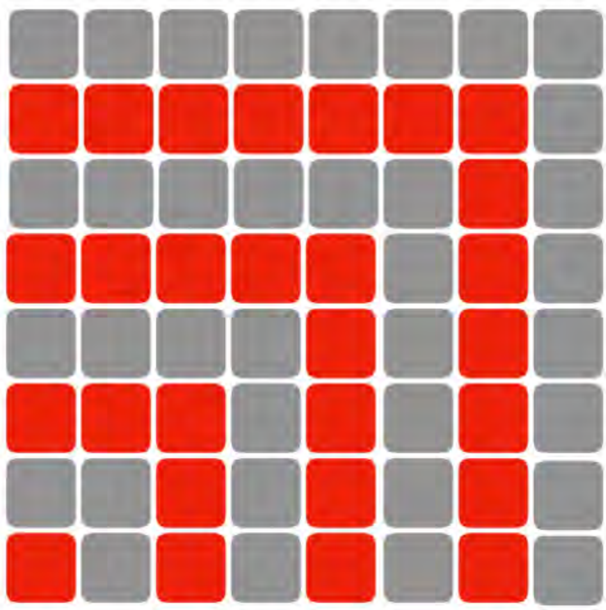
Cultural Heritage between Natural and Artificial Intelligence

Roberto D'Autilia

Abstract

The human interaction with cultural heritage is analysed from the point of view of the artificial intelligence. In this framework a cultural asset is the access point for the mental reconstruction of an era, a cultural environment and a culture. The techniques of machine learning and augmented reality are exploited to reconstruct this space-time mental environment, transforming the use of cultural heritage into a more comprehensive experience. By means of the artificial intelligence techniques the cultural heritage information can be arranged on a graph whose subgraphs correspond to different description of the same topic. Finally an effective example is discussed.

Keywords
conditional probability, artificial intelligence, forecasting, cultural heritage.



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Introduction

These pages are devoted to the comparison of the natural mental models with the models made by means of artificial intelligence for the comprehension of the cultural heritage. The reliability of the two approaches is assessed by the reliability of the comparison of their predictions with the phenomena we are dealing with, making also necessary to clarify what we mean by reality. This apparent philosophical speculation turns out to be useful for the study of the ancient archaeological finds, where the perception of the monuments leads the mind back to the reconstruction of different objects, different times and different contexts [Andrianaivo 2019].

The Conditional Probability

The analysis begins with one of the least intuitive concepts in probability theory: the conditional probability, defined by the well known formula

$$P(A \mid B) = \frac{P(A \cap B)}{P(B)}$$

that states that the probability of the event A, given the event B, is the probability of the common elements of the two events divided by the probability of the event B. If we roll a dice and we get a prime number, then the probability of getting 2 is a conditional probability. A dice has only three prime numbers, $B = \{2,3,5\}$ and the probability of getting 2 is 1/3, but the probability of getting a prime number when we get 2 is 1 because 2 is a prime number: the conditioning is not symmetric

$$P(A \mid B) \neq P(B \mid A)$$

This result is simple, but it is also cause of misunderstanding. In fact, if two events are independent then $P(A \cap B)=P(A)P(B)$ and $P(A)$ does not depend on B:
"*If it is night and a cat appears, we will certainly see it grey, while the mere fact that a cat appears grey does not necessarily mean that it is night: perhaps it is a very bright day in August, but the cat is really grey*" [Marinari 2004]:

$$P(\text{grey cat} \mid \text{it is night}) = 1, \quad P(\text{it is night} \mid \text{grey cat}) < 1$$

A further pitfall is the possible confusion of the conditioning with the cause. One event can be conditioned by another, the two events can be strongly related, but this does not mean that the one is the "cause" of the other. Furthermore, we would not be able to establish which one is the cause and which the effect.
To understand a phenomenon it is then necessary to build a "creative" model that can in turn be suggested by different clues (among them also the statistical correlations). When we have a model we have the possible correlations, but if we have the correlations we don't have a model.
To give an example we may observe that the mail distribution in Italy is statistically correlated with the kangaroo feeding in some part of the Australian forest, but this does not mean that the one is the cause of the other. Once clarified these concepts that will prove to be very useful in the following, we move on to define what the intelligence is.

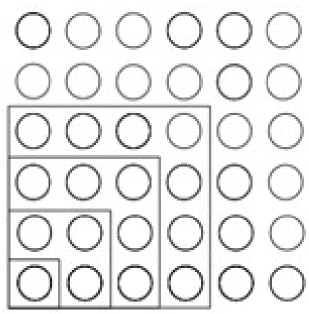
The Natural Intelligence

Defining the intelligence without addressing the vast literature on the subject [Amit 1989; Hebb 2005] is a formidable task, but in these pages we adopt a restricted point of view that will prove to be very useful for the class of problems we are considering. Aware of

the non-exhaustive nature of this definition, here and thereafter we refer to the natural intelligence as the ability to make predictions, assuming this as an operational definition, a not-comprehensive one.
We get an intelligent system if the knowledge of a phenomenon at time *t* enables us to predict its state at time $t + T$. Such a system is a predictor, and the larger the time *T*, the smarter the prediction [D'Autilia 1991]. In this sense, a mathematical formula that gives all the future positions of a planet is a top form of intelligence.

A common example of intelligent behavior is the street crossing. A pedestrian crossing a street should be able to guess the positions of the cars in the immediate future. This prediction could be difficult because it needs assumptions for the motion of the vehicles: a regular, irregular, or even random motion, but in general a very complex one. All these possibilities, together with the experience, set up a mental model that is in fact a predictor for the vehicle position while the pedestrian is crossing the street.

An apparently different example of predictive behavior is given by a theorem. When we observe that the sum of the first *n* odd numbers is $(n+1)^2$, we could ask if this property is always true. It is easy to check this property just looking at the following figure. In fact, adding the next odd number means to increase the side of the square by one unit. We have proved a theorem. This prediction is true forever, as well as the Pythagorean theorem, proved in the 4th century B.C. and true for all the next centuries [Høyrup 2013]. Therefore, in the framework of our definition, we say that the proof of a theorem is the best form of intelligence.



The Artificial Intelligence

To summarise the enormous amount of theoretical and technological achievements in the field of the artificial intelligence in the last 30 years, we could say that the machine learning methods are the most sophisticated way to build statistical correlations between events. Although the most relevant theoretical results on artificial intelligence were obtained more than thirty years ago [Mezard 1987], only for a few years we have had available the computational tools to transform these results into technology.

The artificial intelligence is based on the conditional probability and the estimation of the correlations between inputs and outputs. Very schematically we state that a machine learning system estimates the probability of an output on the basis of a conditional input [Goodfellow 2016]. A deep learning system also looks for nested correlations by addressing the enormous computational complexity with the power of extremely fast and efficient processors. This is a simplification, because even in this field there are differences (for example a branch of the machine learning is devoted to the automatic theorem proving) but in essence, most of the artificial intelligence that we exploit is a way to produce complex networks of statistical correlations.

Given a stimulus, the most popular systems of artificial intelligence return the probability of a response, acting as a sort of feedback system. For the great complexity of the space of the possible responses, a good training makes the machine able to respond also to stimuli for which it has not been trained. This is one of the reasons why artificial intelligence is so widespread in fields ranging from the medical diagnosis to the language translation.

However, a natural intelligent system is a feed-forward apparatus which correlate different and distant phenomena by means of a "creative behavior". Once again we give an example: let us suppose we want to guess the next line of the succession

1
11
21
1211
111221
312211
...

where each line is the verbal description of the previous one: "one one", "two ones", "one two and one one", and so on. In which disciplinary field do we have to train the machine learning system to be able to predict the next line, the arithmetic or the linguistic one? And how do we suggest to the system to make the switch from the arithmetic to the linguistic? This is still an open problem in machine learning, a question dealing with the creativity and the interdisciplinary of the knowledge.

Therefore we say that there are problems that can be faced and solved with the help of the artificial intelligence and problems that can be solved only by means of the natural intelligence. The two sets have an intersection: the tasks that can be faced by both the approaches.
Proof of theorems, inductive inference, correlation among different fields are typical tasks of the natural intelligent behaviour that are currently difficult to deal with artificial intelligence. On the other hand, all the data mining problems, big data, and in general the analysis of large masses of data, can only be treated with artificial intelligence, where some predictive problems such as the street crossing can be addressed in both ways. The scheme loses sense if we realise that artificial intelligence is a tool made by the natural one for dealing with big data and in this sense it is a subset of that. The splitting of the discipline into partially overlapping areas is anyway useful if we want to develop technology, because it makes us aware how much we can rely on the different methods.

The Reality

The last concept we need to make clear before we start talking about cultural heritage is the reality. Again this is a millennial topic of philosophical discussion, but again we stick it into a simple operational definition.

When we listen to a cello player performing a Bach suite, our eardrum receives a signal which is nothing more than the air pressure variation over time. However, our eardrum receive the same signal when the music is generated by an audio file, and the brain of a musician can recreate the same sensations when it is stimulated by the reading of the score. What reality do we imagine that exists besides the signal we are listening? Of course this it is impossible to know without some additional information, and therefore we can only say that the reality is the mere signal we perceive, regardless of its source.

Once we detect a signal, our brain reconstructs the possible underlying phenomenon and a problem arise. In fact, the human brain can imagine the structure of a protein by looking at the 3D model, but it can also reconstruct a kind of "reality" by reading a story from Harry Potter or Dante Alighieri's Comedy. In the case of the proteins the mental model corresponds to a real object, in the second case to a non-real object, but in the case of Dante Alighieri it is a mixture of real and the imaginary facts. How do we evaluate its reliability when we use the augmented reality in this broad sense? The augmented reality can be misleading, but it can also add to the real world extraneous elements that lead to a better understanding of the object we are observing. This is the case of Dante Alighieri's Comedy where the historical facts are mixed with imaginary situations and it is for example the case of the 3D reconstruction of the original shape of a Greek temple. The only possible way out is to consider reality the detected phenomenon, regardless of the nature of the source that generated it. In other words, we make our own the sentence of Bernardo of Cluny "*stat rosa pristina nomine, nomina nuda tenemus*" [Neale 1864] , what is left of the rose is only its name, and we consider reality only a phenomenon that we measure by means of proper tools.
Aware of these limitations and these risks, we establish that these are the ingredients that we want to use to build an interaction tool between people and cultural heritage: artificial intelligence, natural intelligence and a clear definition of the reality we observe.

Archeology

A recent archaeological excavation (the deceased from tomb 132 in the imperial necropolis of Castel Malnome [Catalano 2009]) unearthed a skull of a man whose jaw and mandible were joined together. The study of this archaeological find makes it possible to identify a surgical intervention that allowed the individual to feed and to have a normal working activity. The understanding of this and similar finds led to an in-depth analysis of the workers nutrition during the imperial age. Furthermore the fact that the worker of tomb 132 survived opened the door to an in-depth analysis of supportive and inclusive behaviours in antiquity and to some interesting hypothesis such as the use of ramps for the transport of the sick people in the ancient healing shrines.
The artificial intelligence can be exploited to put all this information together and to create fast switches among them. The web has accustomed us to this approach: when we represent a collection of information together with the links connecting them, the numerous subgraphs of the original graph become possible different points of view. The nodes of the starting graph are the possible reconstructions of the archaeological site, the indices of the scientific literature on the subject or the related studies, where the subgraphs are the possible alternative descriptions of the subject.

Fig. 1. The skull of the tomb 132 of Castel Malnome.

The artificial intelligence is also exploited to index these graphs through an ID with a one-to-one correspondence with the object. The object detection is the access point of the graph, and the graph can be accessed from any of its nodes. By means of machine learning techniques we select the subgraphs related to the interest of the visitors or the scholars or even to address them to fields far from their own specialisation. This logical scheme is the basis of the "tadarc" project [Shazarch 2022], a tool for the recognition of the objects of the Roman forum, the baroque building of Rome or even the entire corpus of the buildings of the city of Turin, returning all the complex graph of information related with that object. In this approach for example, the recognition of the Divo Julio temple in the Roman Forum can lead, on the basis of the visitor's interests, to a philological reconstruction of the temple, to the text of Appiano on the death of Caesar [Appiano 2015] or to the model of Marlon Brando-Marco Antonio in the film by Joseph L. Mankiewicz [Miller 2000].

Conclusions

The enormous technological evolution of the last decade gave us the tools to put together information that comes from different disciplines. By means of the machine learning this information can be used to observe the world on different spatial and temporal scales: from the microscopic to the macroscopic one. At the same time we have the possibility to put together and make accessible these data without distorting the content. This approach allows us to to evolve all the theoretical studies of the last decades into a technology that could change definitely the way the people interact with the history.

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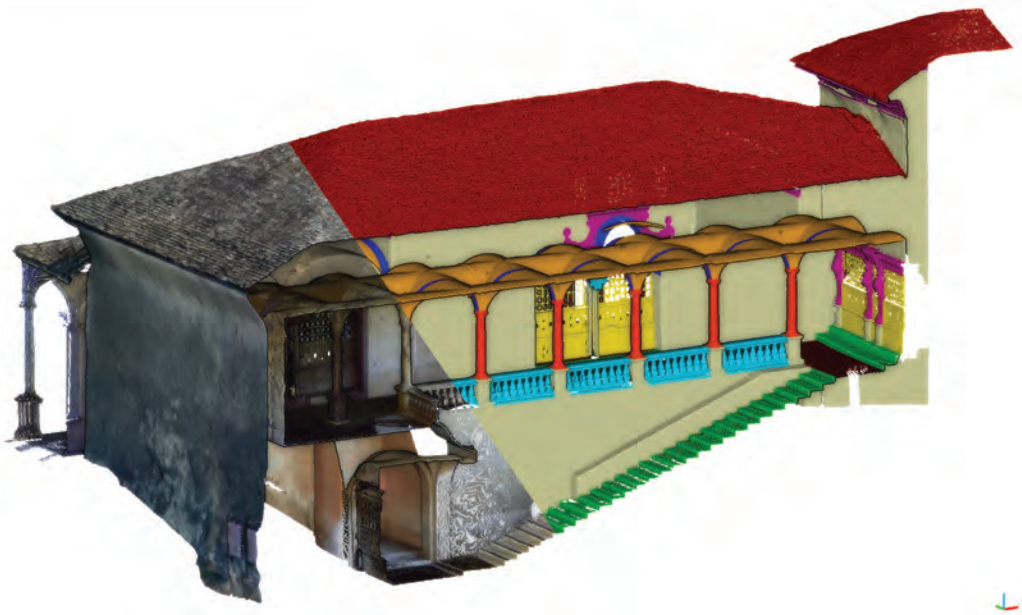
Deep Semantic Segmentation of Cultural Built Heritage Point Clouds: Current Results, Challenges and Trends

Francesca Matrone

Abstract

In the digital Cultural Heritage domain, the ever-increasing availability of 3D point clouds provides the opportunity to rapidly generate detailed 3D scenes to support the restoration, conservation, maintenance and safeguarding activities of built heritage. The semantic enrichment of these point clouds could support the automatization of the scan-to-BIM processes. In this framework, the use of Artificial Intelligence techniques for the automatic recognition of architectural elements from point clouds can thus provide valuable support.
The described methodology allows increasing the Level of Detail in the semantic segmentation of built heritage point clouds compared to the current state-of-the-art through deep neural networks.
The main outcome is therefore the first application of DL framework for CH point clouds, with the subsequent implementation of the selected neural network (the DGCNN) for the semantic segmentation task. These results also permit to evaluate the pros and cons of this approach, along with future challenges and trend

Keywords
semantic segmentation, point clouds, deep neural networks, cultural heritage.



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Introduction

2018 was the *European Year of Cultural Heritage* and, within the related *European Framework for Action on Cultural Heritage*, the innovation and the use of digital technologies to enhance access to cultural heritage (CH) creating digital contents have been highly incentivized, recalling also what stated during the *Council of Europe Framework Convention on the Value of Cultural Heritage for Society* (Faro Convention of 2005).
In this sense, geomatics can bring significant benefits to the CH field. Among the main ones, it allows digital data production to catalogue and preserve historical memory, for the analysis and conservation of assets (movable and immovable), for their fruition even remotely or for the safeguarding in conditions of risk or vulnerability. In particular, point clouds are an increasingly used tool for asset management, and their always greater involvement is mainly due to the latest developments of faster and more efficient acquisition tools such as Mobile Mapping Systems (MMSs). Combining these systems with more consolidated techniques, as terrestrial laser scanning or aerial photogrammetry, allows the acquisition of massive amounts of data, sometimes even excessive. In fact, the generated point clouds are usually subsampled, filtered and post-processed for an effective use and to simplify their management.
This element has created an increasing interest of the scientific community towards the use, interpretation and direct exploitation of point clouds, contributing to the widespread usage of this 3D data also in other sectors such as autonomous navigation, robotics and bioinformatics. Related to this type of data, a new trend has recently emerged in information technology: the *semantic segmentation* of point clouds through artificial intelligence techniques such as Machine and Deep Learning (ML/DL). This tendency allows point clouds to be used as a basis for 3D modelling or as a support for semantic data processing. In the geomatics field, the subdivision of the point clouds into predefined categories (for an architectural or urban/regional scale) entails various tasks: speeding up the reconstruction of 3D models, automating analysis in GIS environments, supporting 3D city modelling, and so on. In particular, it could also be beneficial for the semantic enrichment of HBIM (Historic Building Information Modelling) and to speed up the reconstruction of parametric objects, whose scan-to-BIM process is still entrusted with manual operations. Experts are yet claimed at handling large and complex datasets without the aid of any automatic or semi-automatic method to recognize and reshape 3D elements. These operations are usually time-consuming and, as mentioned above, involve the waste of a large amount of data, given the unavoidable simplification exerted since the objects can be described through a few relevant points or contours.
In this scenario, the comeback of DL has been overwhelming [Griffiths, Boehm 2019a, pp. 1-29], and deep Neural Networks (NNs) settled as the more efficient technology for learning-based tasks [Bello et al. 2020, pp. 1-34]. However, although artificial NNs proved to be very promising for handling and recognizing 3D data, for CH, manual operations still look more trustworthy. There are many reasons for such skepticism; first of all, CH assets have complex geometries, which can be described only with a high level of detail. Moreover, the irregular shapes joined with the uniqueness of objects, make unsupervised learning techniques arduous for 3D data. Besides the intrinsic complexity of 3D data, especially if compared with 2D ones (e.g. images or trajectories), there are other limitations that are hampering the exploitation of deep NNs for CH; on the one hand, the lack of training data, on the other, the computational effort.
To foster research in this direction, it has been implemented an automatic semantic segmentation workflow along with the setting of a newly created database to be used as a common base. Besides, a Level of Detail (LoD) higher than the one achieved in the state-of-the-art for the semantic segmentation of point clouds [Boulch et al. 2018, pp. 189-198; Landrieu, Simonovsky 2018, pp. 4558-4567; Weinmann et al. 2015, pp. 271-278] was likewise required. In fact, among the usual and general categories as building, vegetation, street or vehicle, the *building* class lacks further detail, e.g. *roof, column, stair, arch, floor* or *vault* (Fig. 1) which have been here investigated.

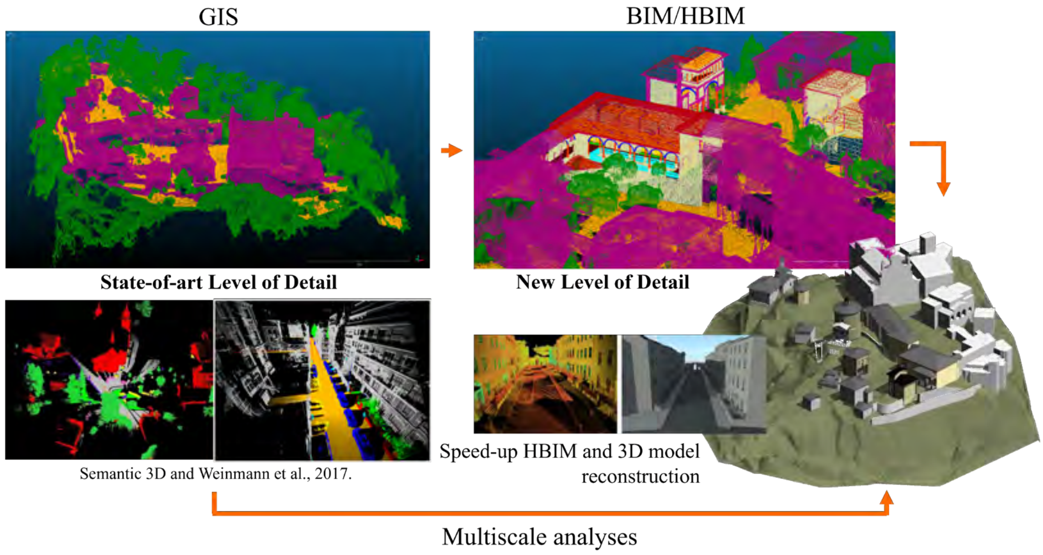

Fig. 1. Comparison between the state-of-the-art LoD for semantic segmentation and the proposed one. On the bottom, the HBIM models obtained from the point clouds.

The research questions this study tried to address are:
• is it possible to operate a multiscale point cloud semantic segmentation from urban to architectural scale? And which LoD should be selected?
• are DL techniques suitable for the CH domain, where the standardization of the elements, which should help automatic recognition, is almost absent?
• what are the pros and cons of the proposed methodology?

Point Cloud Semantic Segmentation Approaches

When dealing with point clouds, it has to be taken into account that they are geometric structures of irregular nature, characterized by the lack of a grid, with a high variability of density, unordered and invariant to transformation and permutation [Zaheer et al. 2017, pp. 3392-3402], making the use of DL techniques not straightforward and even more challenging when dealing with digital CH oriented datasets.

Method	Drawback	Pro
Multiview-based	• Limitations and loss in geometric structures • Laborious to choose enough appropriate viewpoints for the multi-view projection • Information bottleneck: limited exploitation of the potential of 3D data • Duplication of raw data	• Solution to the structuring problems of point cloud data • Easy application of CNN that proved to achieve excellent results
Voxel-based	• High memory and computational power required • Introduction of discretization artefacts • Data loss	• Ordered grid, maintaining the continuous properties and the tridimensionality of the point cloud • Exploitation of the potential of 3D data
Point-based	• Moderate computational power required • Scaling to a larger scene is still unexplored	• Bypassed the structuring problems of point cloud data • Direct exploitation of 3D data, particularly useful for the scan-to-BIM process • Latest trend of using graph NN can help integrating prior knowledge into the model
All	• Large amount of data required for training the model • Mainly focused on indoor scenes or for aerial LiDAR point clouds • Not designed for CH domain • Lack of a comprehensive and labelled CH dataset of point clouds	• Process automation and unsupervised learning in many cases

Tab. 1. Main weaknesses and strengths provided by the exploitation of point clouds with DL techniques.

On the other side, using point clouds make it possible to automate the recognition of the various architectural elements in the object-oriented software and overcome some limitations given by the use of 2D images, such as data incompleteness (given by the lack of three-dimensionality), lighting problems or possible occlusions.

Currently, point cloud semantic segmentation approaches can be divided into three categories [Zhang et al. 2019, pp. 179118-179133]:
• *Multiview-based*: they rely on the creation of a set of images from point clouds, on which Convolutional Neural Networks (CNN) can be applied;
• *Voxel-based*: they consist in the rasterization of point clouds in voxels, which allow having an ordered grid of point clouds, while maintaining the continuous properties and the third dimension, thus permitting the application of CNNs;
• *Point-based*: the classification and semantic segmentation are performed by applying feature-based approaches, directly exploiting the point clouds.
The main strengths and weaknesses of the point clouds exploitation methods, defined on the basis of the literature review, are reported in Tab. 1.

Selection of neural networks for testing

Based on the considerations presented in Table 1, the point-based methods were chosen for the semantic segmentation in the CH domain, even if recent studies apply also other approaches [Pellis et al. 2022, pp. 429-434]. In particular, among the networks proposed in the state-of-the-art, the deep NNs selected for this study have been: PointNet [Qi et al. 2017a, pp. 77-85], its extensions PointNet++ [Qi et al. 2017b, pp. 5100-5109], Point CNN [Atzmon et al. 2018, pp. 1-14] and the ***Dynamic Graph CNN***, *DGCNN* [Wang et al. 2019, pp. 1-12]. The latter addresses many shortcomings of the previous works and consumes point clouds through graph structures.
With respect to these four deep NNs, the DGCNN has proved to achieve good results with the proposed dataset; therefore, it has been deepened and modified for the purposes of this research. PointNet++ and Point CNN (PCNN), on the other side, were less generalizable, and they seemed to work well mainly with small datasets and simple classes as in the case of ScanNet. Their results have been described in [Pierdicca et al. 2020, pp. 1-23].

Dataset

From the state-of-the-art investigation, it emerged that there are few datasets specific for some CH areas, such as [Korc, Förstner 2009; Teboul et al. 2011, pp. 2273-2280; Tyleček, Šára 2013, pp. 364-374]; nevertheless, they only provide bidimensional data, and they mainly consist of manually annotated façade images from different cities around the world and diverse architectural styles.
Regarding 3D data, an interesting project named OpenHeritage 3D has been proposed to provide open access to 3D CH datasets and foster community collaboration. However, only not labelled point clouds are available.
Precisely for these reasons, it has not been possible to identify one suitable dataset; hence an *ad hoc* one has been created.
The created dataset constitutes a new 3D large-scale benchmark for heritage point clouds (named *ArCH dataset – Architectural Cultural Heritage*) with millions of manually labelled points belonging to heritage scenarios [Matrone et al. 2020, pp. 1419-1426].
It has been made available for the scientific community, and it originates from the collaboration of different universities and research institutes (Politecnico di Torino, Università Politecnica delle Marche, FBK Trento, Italy, and INSA Strasbourg, France), offering for the first time, annotated point clouds describing heritage scenes.

Methodology

In the following section, the DL framework based on the DGCNN and its implementation [Pierdicca et al. 2020, pp. 1-23] will be only briefly outlined, giving more prominence to overall discussions and considerations on the method, highlighting the main results obtained with the relative pros and cons and the challenges to be faced for the next future.
Generally speaking, a symmetrical scene was chosen to perform the preliminary tests to set the network (Fig. 2, part 1); then its generalization capability was tested, training it from scratch on multiple scenes (Fig. 2, part 2), finally, the best configurations were tested on the whole ArCH dataset (Fig. 2, part 3).
The achieved results are compared with the Ground Truth (GT) in terms of *Overall Accuracy* (OA), *F1-Score*, *Precision*, *Recall* and *mean Intersection over Union* (mIoU).

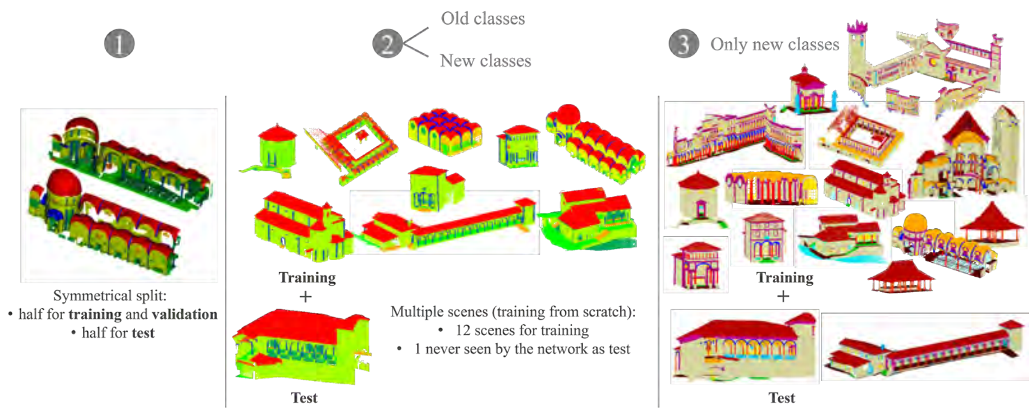

Fig. 2. Overview of the tests subdivision.

k-NN and Hyperparameters Setting

Once chosen the DGCNN, it was necessary to adapt it to the ArCH dataset.
To do this, a symmetrical point cloud was first selected from the dataset to efficiently carry out the preliminary tests on the network with moderate calculation times and computational power. In fact, the scene was split into two parts along the symmetry axis: one half was used as a training/validation set and the other half for testing. This method allowed setting the hyperparameters and provided the basis for all subsequent tests.
In the original DGCNN the analysis of the scenes takes place through endless *blocks*, interspersed with a certain *stride* (Fig. 3).
A certain number of subsampled points to be used as input for the network is then defined within each block. Therefore, it has been assessed whether different types of subsampling of the initial point clouds (*octree* or *space*) could affect the final performances. As a result, *block size*, *stride* and *number of subsampled points* were the first hyperparameters to be tested.

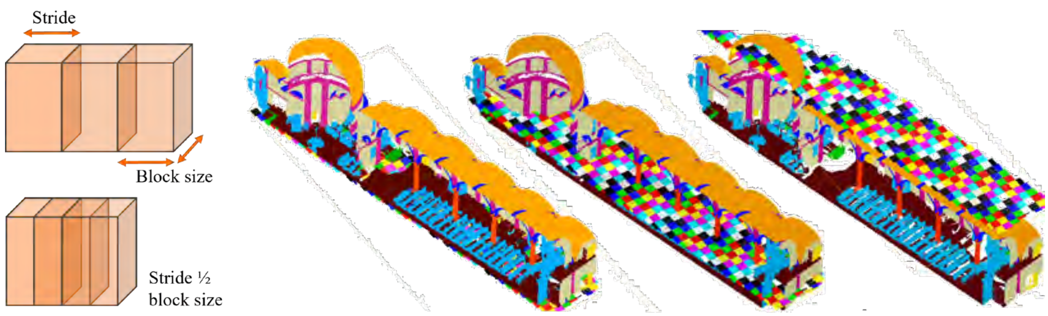

Fig. 3. The relation between stride and block size and footprint of the endless blocks along the half scene of the Trompone church to highlight the scene subdivision.

Since the ArCH dataset's point clouds also contain the radiometric component (expressed as RGB) and normal vectors, these values were also used as input for the network. In the original DGCNN at the input layer, k-NN is fed with normalized points coordinates only, while in this proposal all the available features were used. A scene block is thus introduced into the DNN, composed of 12 features for each point: *x y z* coordinates, *x' y' z'* normalized coordinates, 3 colour features (RGB or its conversion into Hue Saturation Value channels – HSV – or L*a*b*) and *Nx Ny Nz* normal vectors. This architecture was named DGCNN-Mod (Modified).

Class Imbalance and DGCNN Implementation

The results of the preliminary tests highlighted a relevant issue of class imbalance. In fact, all evaluated approaches failed in recognizing classes with low support, as *doors*, *windows* and *arches*. Besides, for these classes, high variability in shapes across the dataset was noticed [Pierdicca et al. 2020, pp. 1-23], and this element probably contributed to the networks' poor accuracy.
To remedy the class imbalance, several different approaches have been proposed in the literature, e.g. [Buda et al. 2018, pp. 249-259; Pouyanfar et al. 2018, pp. 112-117; Ando, Huang 2017, pp. 770-785; Griffiths, Boehm 2019b, pp. 981-987]. Among these proposals, the change of the loss function and data augmentation techniques, focused only on the minor classes, have been selected. In particular, according to the work of [Lin et al. 2020, pp. 318-327], a new type of loss has been chosen and implemented in the DGCNN: the focal loss. It is designed to solve the issue of the imbalance down-weighting the classes containing more examples to target the training on the categories with fewer samples.
It was then decided to help the network with ad hoc features to discriminate the classes. Based on the insights of [Grilli et al. 2019, pp. 541-548; Weinmann et al. 2015, pp. 271-278], a few 3D features were introduced to evaluate whether their contribution could be similar to that produced with ML classifier as RF. These 3D features derive from a compound of eigenvalues ($\lambda 1>\lambda 2>\lambda 3$), and they can describe and emphasize the different architectural elements in a particularly explicit way. Those selected have been *verticality* (f1 and f3), *omnivariance* (f2), *surface variation* (f4), *planarity* (f5) and *z value* (f6) (Fig. 4), so the new complete input data is ordered as follow: *x, y, z, R, G, B, f1, f2, f3, f4, f5, f6, Nx, Ny, Nz*.

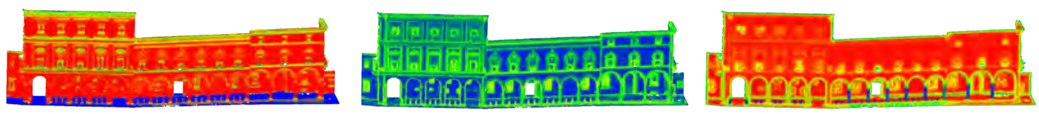

Fig. 4. Example of 3D features extracted and relative radius.

With these new 3D features, the performance of the DGCNN-Mod is compared with two novel versions of this network: the DGCNN-3Dfeat and the DGCNN-Mod+3Dfeat. In particular, the DGCNN-3Dfeat adds to the k-NN only the 3D features; whereas, for a complete comparison, the DGCNN-Mod+3Dfeat comprises all the 18 available features [Matrone et al. 2020b, pp. 1-22].
The positive insights of 3D features and eigenvalues led to consider the option of concatenating them to those learned from the network so that they could be available in the last layer before the semantic segmentation task. This procedure, theoretically, should lead to using the features with their informative contents as they are, and not reworked by the deep NN, adding new info to what has already been learned, and improving the model convergence. Based on [Huang et al. 2017], a new structure has been thus created to concatenate the initial 3D features with the last layer, defined as skip connection.
Besides, a DL approach can also be improved by using particular data augmentation

techniques on the training data. This solution is quite common with images, where colour space augmentations, random part exclusion, geometric transformations, kernel filters and so on can be applied and could also be used to prevent class imbalance. Many of the usual techniques cannot be chosen with point cloud data, but there are other methods, where the point cloud is augmented on-the-fly. In this case, rotation, clipping, spatial shifting, jittering and scaling strategies have been implemented along with transfer learning techniques [Matrone, Martini 2021, pp. 73-84].

Results and Discussions

The results obtained allowed an increased Level of Detail in the semantic segmentation of built heritage point clouds.
Specifically, the literature review has made it possible to identify several criticalities in the application of the DL framework to the CH domain, in particular:
• the scarce development of DL techniques for this domain and, even less, applied to heritage point clouds;
• the lack of an adequate LoD for the semantic segmentation of CH point clouds;
• the absence of a dataset consistent with the aims of this research.
Precisely for these reasons, the ArCH dataset was expressly created to provide a starting point for future developments in this field; however, it does not constitute a sufficiently exemplary dataset of the multitude of architectural cultural elements, very variable and different from each other across the various architectural lexicons.
For the annotation of this dataset, a Level of Detail equal to 3 was selected, according to the CityGML standard. This LoD improves the one present in the state-of-the-art, but on the other hand, it can be further increased only in proportion to the size of the datasets available for the DL techniques.
The results of the tests performed highlighted the importance of introducing normal vectors (and even more their correct orientation) and the radiometric component. Concerning the latter point, the test performed to investigate the relation between the colour channels and the individual classes showed that the use of HSV led to a slight increase in the performances. Regarding the subsampling method, the variation in the results between octree and space-based methods was about 1% of OA in favour of the octree. In this case, the immediacy of the space-based method was chosen for the following tests, even if with slightly lower results.
With this configuration, 73% of OA was obtained for the symmetrical scene and 83% of OA for the tests conducted with part of the benchmark scenes as a training set. These first results showed a good recognition of those classes represented by more points in the training set, and a significant criticality for the categories with fewer points. Class balancing has, therefore, turned out to be one of the main issues to be addressed. The introduction of focal loss, to overcome it, did not guarantee overwhelming results. In fact, the arch class was the only one to improve its metrics, while for the other classes with fewer points (column, door/window, stair and molding) common pattern could not be identified.
The introduction of 3D features is the element that, most of all, boosted the performances of the network: in the symmetrical scene, it led to an increase of about 10% of OA, while with an unseen scene of about 3%. Although the gain in OA is smaller in the second case, if the classes with a low number of points are considered, it emerges that almost all of them improve their metrics with the use of 3D features. Considering the F1-score: arch + 1%, column + 43%, door/window + 16%, stair + 14% are obtained. Therefore, it can be said that their introduction, associated with the use of focal loss, has led to the expected results.
The skip connection's introduction, to further improve the model convergence, resulted not very effective in terms of OA, but useful for discriminating some specific classes such as molding and door/window. Comparing the F1-score between two tests with and without skip connection a + 6% for the molding and + 2% for the door/window are recorded.

The data augmentation approach has confirmed a viable path for point clouds, even if, as described for the previous tests, it was impossible to identify a common pattern: some classes are discriminated better than others alternately, depending on the combinations of hyperparameters used.
Broadly speaking, to pursue DL generalization, the classic solution of expanding and implementing the training set is still the most suitable one, but the lack of additional datasets remains a compelling criticality for future developments.
In conclusion, after choosing the approach and the deep NN to be implemented, it has been possible to step from an initial 56.1% of OA up to a final 86.3% (86.6% with the whole ArCH dataset) (Fig. 5).

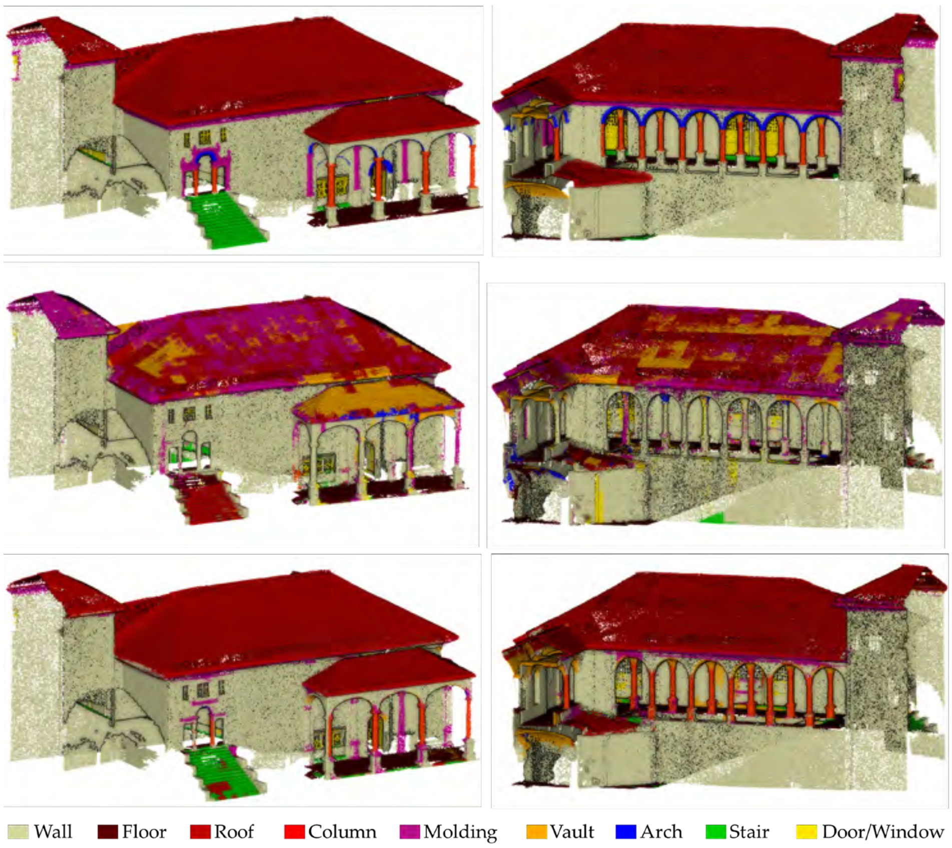

Fig. 5. Ground truth (on the top), the prediction of the first test with the DGCNN (in the middle) and the final test with the DGCNN-Mod+3Dfeat (on the bottom). The represented point cloud is one of the two test scenes of the ArCH dataset, and it belongs to the Sacro Monte of Varallo (SMV).

Conclusions: Future Perspectives and Challenges

Recalling the initial research questions it can be stated that it is certainly possible to increase the Level of Detail for the deep semantic segmentation of point clouds representing buildings or architectural assets. In particular, to date, it is feasible to reach a LoD equal to 3 with point-based approaches.
Although the CH domain is characterized by patchy elements and, consequently, poorly standardized, the creation of a new annotated dataset has provided the basis for the application of DL techniques even on CH point points. Currently, given the lack of labelled data, ML classifiers (such as Random Forest) are an excellent alternative, but they do not define the winning solution.
Based on the obtained results, future developments of this topic may consist in the integration of an ontological structure or taxonomy within the neural network, in order to guide and eventually correct it in the learning phases and the automatic training data generation to increase the dataset size.

The methodology proposed includes, among its strengths, the possibility of guaranteeing unsupervised learning, thus limiting the manual intervention of operators in processes such as the scan-to-BIM. In addition, feature engineering is less time-consuming with respect to other classifiers since the neural network can automatically learn the discriminating features. Finally, a good generalization and a high tuning capacity of the hyperparameters is also guaranteed.
The weaknesses, on the other hand, reside in the training set size dependencies, training time (strongly dependent on the hardware used and still higher than traditional classifiers) and unbalancing of the classes. This last aspect is undoubtedly a challenge for deep learning techniques applied to point clouds and, even more, for the CH field. As for the other disadvantages mentioned above, they will be partially solved in the next future with the continuous technological developments, which will assure ever higher computational powers. Regarding the scarcity of labelled datasets and tests, it should be noted that recent studies e.g. [Wysocki et al. 2022, pp. 529-536; Cao, Scaioni 2022, pp. 1-22; Pellis et al. 2022, pp. 429-434] are focusing on this topic, thus contributing: i) to the diffusion of the dataset, ii) to its extension and iii) to the improvement of NNs' performances trained on built CH point clouds. Likewise, a further research trend linked to the semantic segmentation task consists in using the output of artificial intelligence algorithms as input for additional processing, e.g. scan-to-BIM procedures [Croce et al. 2021, pp. 1-34] and/or mixed reality [Teruggi et al. 2021, pp. 155-162].
The scientific community's increasing and compelling interest in point cloud processing and semantic segmentation certainly leaves hope for excellent future prospects.out skip connection a + 6% for the molding and + 2% for the door/window are recorded.
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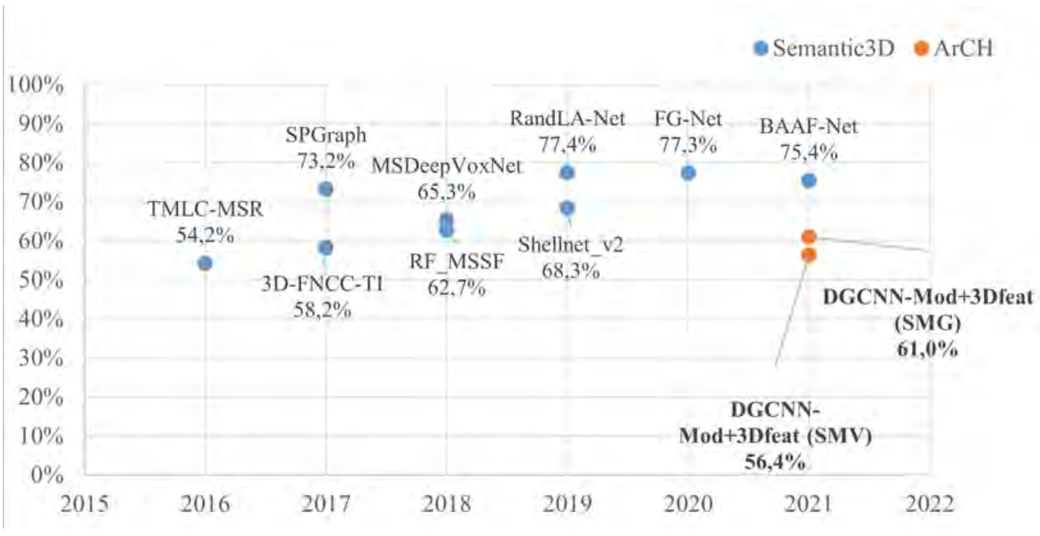

Fig. 6. Comparison with the state-of-the-art performances of Semantic3D benchmark compared to ArCH in terms of mIoU. SMV and SMG correspond to the two test point clouds of the ArCH dataset.

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The scientific community's increasing and compelling interest in point cloud processing and semantic segmentation certainly leaves hope for excellent future prospects.

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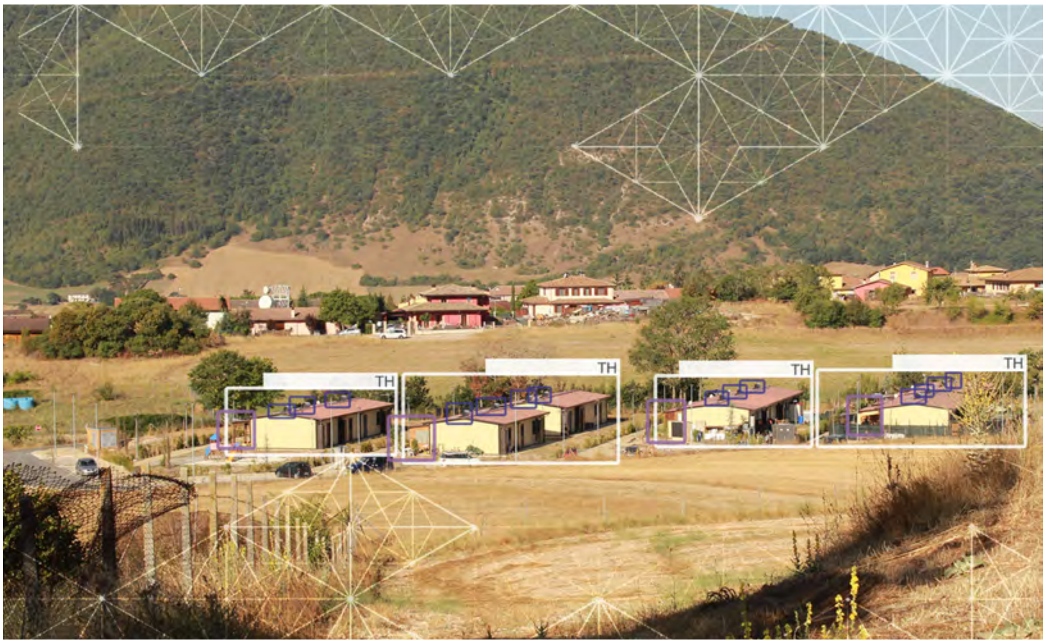
Augmented Intelligence In Built Environment Projects

Camilla Pezzica

Abstract

Ever-increasing levels of digital connectivity and ubiquitous sensing capacity offer opportunities to rethink traditional design and planning practices towards delivering more sustainable and resilient futures. Within this context, the chapter discusses how digital representation, Artificial Intelligence and collaborative processes can enable coping better with uncertainty by informing design and environmental management moves. Through two distinct examples, one in the UK and one in Italy, it illustrates how data about the built environment can be collected, networked, and operationalised to deal better with complexity and make informed decisions which consider alternative courses of action and challenge pre-existing assumptions. Both cases presented highlight the importance to establish a two-way link between digital and physical infrastructures and the people.

Keywords
AI, architectural design, decision-making, digital representation, modelling, urban planning.



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Towards the People-Smart Sustainable City

Cities are considered hubs for the transformative change required to protect the prosperity of present and future generations [Golubchikov 2020]. In fact, they can support a larger social and infrastructural webbing and promote civic innovation and people-centred design and management, through the integration of sensors and Information and Communication Technologies (ICTs) and the development of Artificial Intelligence (AI) applications [Duarte, Ratti 2021; Kandt, Batty 2021]. However, technology-centric and narrow-focused smart city approaches oversimplify problems and wrongly assume that these can be solved solely by having access to smart infrastructure [Boykova et al. 2016]. Digital platforms are often built to promote profit rather than open information sharing and relationality [Barns 2021] and some smart city projects risk generating a loop in which more of the same is delivered.

In response to this, Andreani et al. [2019] suggest to achieve the required socio-technological hybridization and recover the human scale by adopting a design-oriented approach, considerate of the complexity and diversity of contemporary urban environments. For delivering socially oriented solutions which generate value for all, setting up the right conditions for the exploitation of digital technologies in the design and management of built assets seems certainly critical. To this end, the chapter suggests developing intelligent pathways, which facilitate collaboration among the many actors involved in the shaping and conservation of contemporary urban landscapes and support their decision-making process. This requires adopting a decision-driven approach aimed at producing nuanced information to answer specific questions rather than at generating unidimensional solutions; what implies looking at existing data and collecting new ones.

The chapter illustrates the potential value of this proposition through two distinct cases in which digital representation and AI were used to support problem understanding, via modelling and analysis, as well as the development and evaluation of alternative design and planning decisions. These belong to two recent research experiences, one in the UK and one in Italy: (i) the "Shelf-life" project, funded by the Arts and Humanities Research Council, which focused on the Carnegie libraries of Britain [Prizeman et al. 2018]; and (ii) a fully-funded PhD research about Temporary Housing (TH) post-disaster [Pezzica 2021].

The goal of these projects was, in order, to foster intelligent conservation and Building Back Better practices and they both carefully considered time and change as part of their discourses. These two cases adopt different perspectives and provide a variety of real-world examples, which enable a broad ranging discussion about the use of digital representation and AI in built environment projects, including their application in supporting decision-making and scenario exploration. Although they differ in several aspects, these projects have in common a focus on social and environmental sustainability and they both propose using digital representation and AI to generate digital models, rich in useful information, which help grounding complex decisions in theoretical reasoning and critical reflection while promoting open sourcing and collaboration.

Promoting Intelligent Conservation Practices: Shelf-Life Project

When Carnegie libraries were built around 100 years ago, through the uniquely controlled procurement of the homonymous steel magnate and philanthropist and his trust, electric lighting was expensive and heating cheap. These buildings were engineered to capture daylight as a priority to benefit readers, e.g., via the use of large skylights, glazed ceilings and partitions. The libraries were also naturally ventilated to safeguard public health via the use of ventilation turrets and grilles, vaulted ceilings, and domes, among other elements, as protecting the public from airborne diseases was a key concern at the time. Since their design aimed to satisfy energy performance requirements which are diametrically opposite to current ones

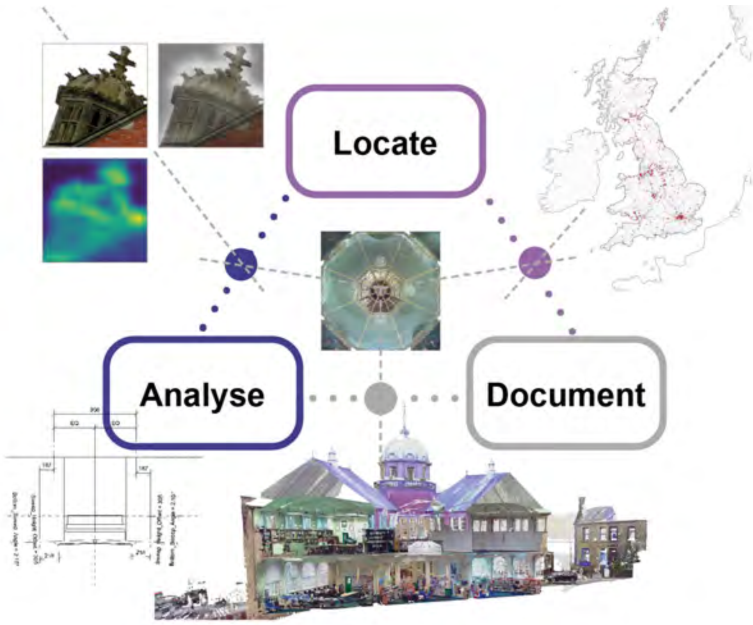

Fig. 1. Shelf-life project framework.

[Prizeman 2017], Carnegie libraries are increasingly being sold and re-purposed. To date, their characteristic features have often been made redundant and are seen as contributors to the buildings' reduced thermal efficiency and increased risk of water leakage. The fact that most of them have been granted heritage status is often perceived by local administrators as an additional problem, and current imperatives of energy use reduction and requirements for physical accessibility put these libraries at risk of closure.

The Shelf-Life project poses that the conservation management of public buildings should be informed by both technical and historical understanding and that quantitative indicators used for audits should be qualified by nuanced and context-based readings of design and operational intent. Thus, it combined a broad range of digital methods and tools to reflect systematically about the re-vitalisation of thousands of Carnegie library buildings across the UK and the USA, and formulate critical approaches to their refurbishment, so they can continue promoting culture and wellbeing. The project specifically explored functional and morphological relationships between single architectural components and the whole building. This enabled promoting a wider and deeper understanding of the libraries' original design and environmental performance drivers and augmented the legibility of technology and construction systems which might have potential for reappraisal [Prizeman, Pezzica et al. 2020].

Linking Digital Representation and AI: Architectural Scale

The research followed the three-steps framework shown in Figure 1. Initially, all the surviving Carnegie library buildings in Britain were mapped (Locate). This required using many information sources (e.g., scientific publications, archival documents and historical maps) and then confirming their status through a physical survey, during which all surviving buildings were digitally photographed (Document). The images collected were used to assess the quantity and relative incidence of common features using a deep classifier (Analyse). A group of 23 libraries was selected to be digitally recorded using terrestrial laser scanning and photogrammetry to produce a 3D dataset with the metric information required to create a set of parametric families of typical architectural components in Historic Building Information Modelling (HBIM). To facilitate the association of architectural and construction histories to the 3D models, it was proposed to exploit image classification methods again to match illustrations with pictures or corresponding elements, as there is scope to use adverts to link some of the libraries' characteristic components to manufacturers that are still in operation [Prizeman 2015]. This workflow enabled correlating data (e.g., build date, architect, plan configuration, listing designation status, notes on condition, materials, components, location etc.) for all the Carnegie libraries of Britain. The output digital resources include a GIS interactive application, a semantically tagged photographic gallery, a deep learning model for the classification of selected architectural features, and a set of HBIM families, all accessible at [Prizeman, Pezzica 2020].

Subsequently, publicly available energy data was collated and analysed using an interactive dashboard to challenge current assumptions about the libraries' presumed poor energy performance [Prizeman, Boughanmi et al. 2020]. To this end, a whole building model supporting Life Cycle Analysis (LCA) calculations was also created, and a few others were used to study the functioning of Carnegie libraries' natural ventilation system via Computational Fluid Dynamics (CFD) analysis.

Aspects of Technical Implementation: "Shallow" vs Deep Models

In the Shelf-Life project digital representation and AI were used to draw and share the advantages of generalisable results, by looking at standardised architectural components. To this end, in [Pezzica, Schroeter et al. 2019] the performance of a high-end Machine Learning ($F1_{ML}$=0.56) and two Deep Learning classification models ($F1_{CNN}$=0.78, $F1_{FPN}$=0.82) was comparatively assessed for 4 classes of features using their mean F1-scores. This study concluded that deep learning, and particularly a Feature Pyramid Network model, is preferable in this application. The test involved training 3 supervised classification models using the image data collected in the survey phase: 424 photos of external façades and 224 of libraries' interiors, generating ~4,000 photo crops which were labelled using 4 keywords. Random samples of backgrounds were also used to train the model (using the tag "other") while several copies were generated for each image, following random transformations as part of a data augmentation process. This, and the availability of a critical mass of observations, enabled a sensible model sizing and training, overcoming risks of poor performance due to overfitting.

Deep learning models present an end-to-end architecture, i.e., they train simultaneously representation learning and classification, tailoring the learning of features to the needs of the classification task at hand. Thus, differently from traditional machine learning methods, they do not require generating input features independently of the training process. Moreover, they help overcoming common issues in image datasets such as distortions and occlusions even with no hyper-parameter tuning; what makes them a better fit when using imperfect (collaborative) data. Although a downside is that deep classifiers are seen as black boxes, explainable AI tools can be used to understand the underpinning of their internal decision-making processes. To provide a degree of control over the classification results, in this project coarse localisation maps were generated from Grad-CAM to check what visual information the FPN model used to classify an object correctly.

Building Back Better: TH project

TH assistance projects are commonly delivered after disasters, in conditions of uncertainty and time pressure. Although easier to implement in this context, one size fits all TH solutions have often proved unsuccessful and short-sighted, detracting resources from development [Borsekova, Nijkamp 2019].

In Italy, after the criticisms of the centralised and top-down response to the 2009 L'Aquila earthquake, local administrations have been given increasing responsibilities over the delivery

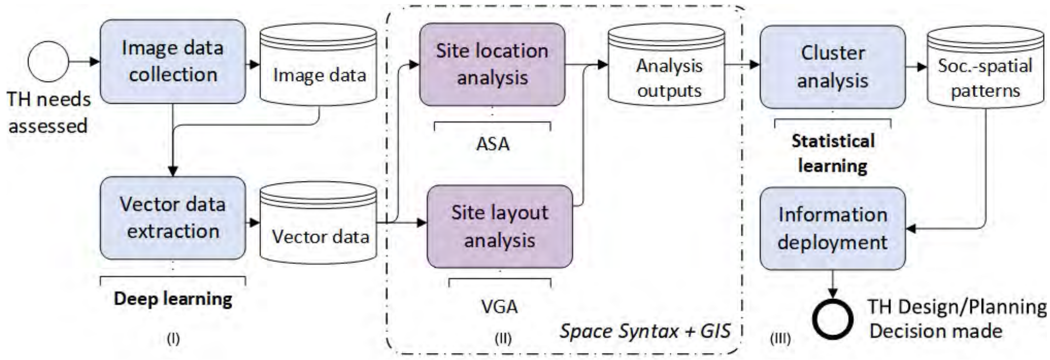

Fig. 2. TH project analysis framework.

of TH plans, including proposing and evaluating the location and layout of the TH sites. Yet, in the aftermath of the 2016-2017 Central Italy earthquakes, they were offered only limited support and generic guidance (e.g., select sites close to the destroyed city, limit land consumption, favour terraced housing arrangements) to undertake the task. Furthermore, the TH planning and delivery process, which was set up centrally, allowed room for discretionary decisions and little space for bottom-up inputs, leaving unresolved problems concerning damage assessment and the choice of TH sites' location and layouts [Pezzica 2021].

The TH project poses that enabling an equitable and developmental disaster recovery requires the adoption of well-informed and place-sensitive TH planning practices. Therefore, it seeks to mainstream the generation of digital information packages relevant to the design and planning of TH sites, which enable a formal verification of TH outcomes in the medium- and long-term, at multiple levels. The proposal is tied to action and involves methods to rapidly harvest and mine data produced though collaborative mapping by civic activists and volunteers. The project exploited the opportunities offered by the diffusion of low-cost imaging devices, increasingly accessible digital technologies and software solutions (collaborative platforms), as well as open data and code produced to support post-disaster humanitarian operations. It combined digital representation and machine learning to: (i) help document disaster-affected towns; and (ii) visualise changes in patterns of urbanisation and transportation as part of scenario-based assessments. The scenario production and auditing required modelling and analysing the spatial configuration of TH plans at multiple scales and times, considering various network centrality and resilience indices.

Linking Digital Representation and AI: Urban Scale

Figure 2 shows the proposed decision-driven TH analysis framework. This is focused on answering practical design and planning questions and encompasses: (I) data understanding and preparation; (II) scenario modelling and analysis; and (III) results evaluation and interpretation for information deployment.

In part (I) the project examined the possibility to use street level images collected by citizen scientists during participatory photographic mapping initiatives to support 3D reconnaissance operations and TH spatial planning, through the rapid and economic construction of photogrammetric models and vector data/maps. It also explored under which conditions collaborative photogrammetry can empower local communities and promote ownership of results, fostering civic participation in recovery by means of recording buildings and urban structures. To this end, a test was done using 4 image samples of selected urban fragments, whose 3D outputs presented varying quality levels. A framework to draft better image capture guidelines for citizen scientists was then developed, besides suggestions for exploiting multi-sensor data integration within fit-for-purpose digital documentation workflows [Pezzica, Piemonte et al. 2019]. Additionally, it was proposed the use of AI-powered image classification models (similar to those explored in the Shelf-Life project) to support the images' semantic-enrichment and open-sourcing, i.e., the automatic extraction of geo-spatial vector data such as Points Of Interests (POIs) from them.

In part (II), collaboratively produced vector map data (mainly road centre lines, administrative limits and building footprints from Open Street Map) was used to set up different configurational analysis models, suitable to evaluate alternative TH planning and design options and propose corrective planning actions. The analysis evaluates primarily the sites' spatial accessibility (ASA, Pezzica et al. 2020) and the permeability of their layouts (VGA, Chioni et al. 2021) and adopts an established theory of space and society known as Space Syntax, which understands urban spaces as components of a wider network system. The geography of the destroyed city, and how this changed immediately after the disaster and following the construction of TH sites, are analysed with an eye to that of the city after the reconstruction, to assess modifications in their spatial logic. Thus, the multi-scale study of 4 towns hit by the 2016-2017 central Italy earthquakes produced a high-dimensional matrix of floating numbers, each describing a key network property of the different configurations (Fig. 3).

In part (III) machine learning was deployed to synthetise this multidimensional information, otherwise difficult to aggregate and systematically interpret, in a format suitable to inform urban design and planning decisions. After performing the necessary data preparation steps, a classical agglomerative Hierarchical Clustering (HC) algorithm was used to group together the urban street network configurations in an iterative way so that deeper analogies could be identified starting from the configurational values which were previously calculated [Pezzica et al. 2021]. At the neighbourhood level, a group of 20 TH sites' layouts was analysed to extract several indices useful to identify similar spatial patterns, beyond the simple typological distinction between detached, row-, and courtyard housing. Using the analysis data, 3 different clustering algorithms (HC, K-means, FCM) were adopted to explore within a dashboard how well the form of different TH sites' layouts matched their intended function in post-disaster recovery and reconstruction [Pezzica, Cutini 2021].

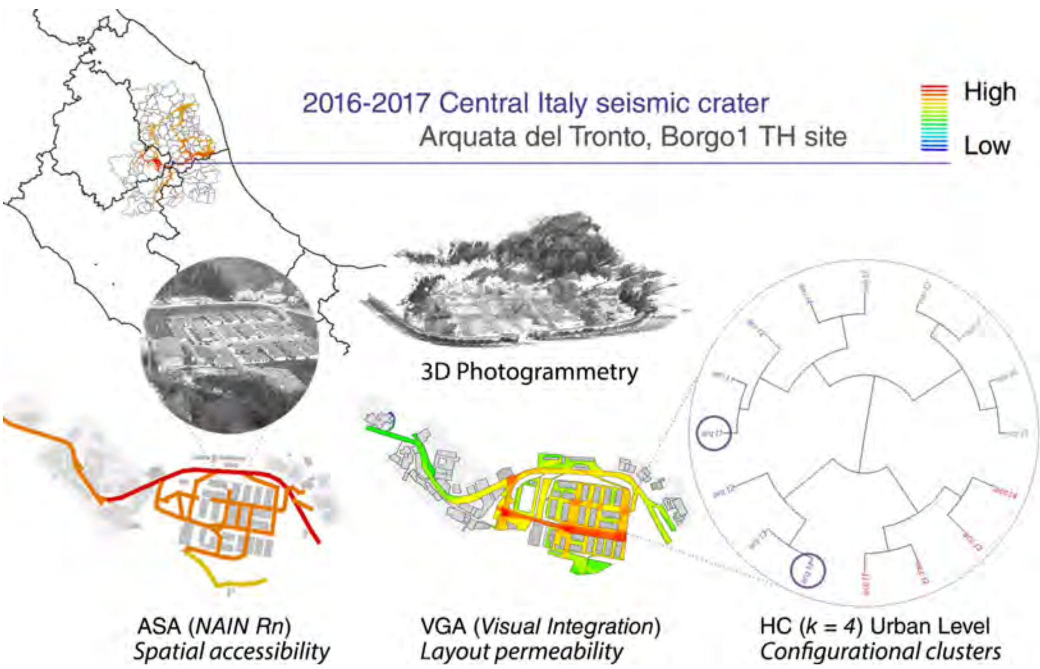

Fig. 3. Configurational analysis of Borgo1 site, Arquata del Tronto.

Discussion and Conclusions

The chapter discussed some of the opportunities and practical challenges of using AI and digital representation for augmenting intelligence in built environment projects and argued that their successful exploitation in design and planning requires well-informed and action-oriented – not simply data-driven – decision-making.
Specifically, the experience of the Shelf-Life project suggests that digital representation tools and AI methods can support the construction of cost-efficient knowledge sharing structures, which promote sensitive and economic approaches to the rehabilitation and re-use of historic buildings. In fact, they enable mapping families of common architectural components, through the automated recognition of features relevant to HBIM, and then pooling useful resources at scale. Besides help counting the instances of selected elements, they can inform 3D modelling and semantic enrichment processes. This enables exploring relationships among interrelated architectural elements which operate at a wider level as part of standardised systems, and which are characteristic attributes of a particular building typology, epoch, or geographic region. The proposal ultimately facilitates linking relevant technical literature, environmental models and HBIM components to identify buildings which share similar conservation issues and foster possibilities for mutual information exchange on best practice. It provides a valuable pathway for the organisation of relevant information in accessible and open formats and fosters the targeted dissemination of informed HBIM data, towards enhancing data exchange processes. What opens possibilities for codifying, identifying and informing intelligent conservation and repair strategies for several building typologies where architects specified similar features. Notably, as the quantity of features recorded becomes greater, so does the ability to infer historic design intent.

Changing context, the TH project indicates that digital representation and AI can contribute to enhance community advocacy and deliberation and foster a more longsighted and human-centered TH assistance delivery after disasters. Combined with the proposed spatial analytical approach, they can effectively support the comparative assessment of multiple TH planning scenarios and the proposition of fine-grain urban design adjustments, considering local patterns and temporal transformations. At the urban scale, this enabled differentiating between TH plans which are likely to initiate a process of urban decentralization (the relocation of commercial activities outside the historic city centre) and best practices, i.e., TH plans which contribute to increase the resilience of the local street network, without modifying the spatial logic of the destroyed city. At the neighbourhood scale, this enabled spotting a weak correspondence between TH sites' form and function, as well as inefficiencies in the use of physical resources in recovery and reconstruction. By facilitating a formal audit of post-disaster recovery trajectories, this approach can promote the construction of better TH schemes, which add to the resilience of local infrastructures and respond to the aspirations of local communities (e.g., by retaining in TH sites some of the visual and spatial permeability properties of the destroyed city). If combined with post-occupancy studies, the proposal offers opportunities to enhance strategic planning by supporting the definition of context-based socio-spatial performance targets to include in future framework agreements for TH supply and delivery.

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"Divina!"
a Contemporary Statuary Installation

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Michela Belli

Abstract

In 2021, the year of the 700th anniversary of Dante Alighieri's death, the ASTRO Laboratory of the Pisa University Department of Civil Engineering have set up, in collaboration with the Tuscany Regional Council, the contemporary statuary installation "Divina!" based on the work of the great poet. This installation leads users to ponder, from a technological standpoint, the way in which the means of communication are used and the importance of preserving and conserving the roots of linguistic evolution.

Keywords
Divina Commedia, interaction of technologies, facial recognition, contemporary statuary installation.

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Introduction

The year 2021 was characterized by several initiatives aimed at commemorating the 700th year since the death of Dante Alighieri, occurred in exile in Ravenna between September 13 and 14, 1321. Among these initiatives, the Authors wanted to pay homage to the universally acknowledged father of the Italian language and bring to the attention of Italians the enormous artistic and literary heritage bequeathed to the posterity by Dante. In this context, the ASTRO Laboratory of the Pisa University Department of Civil and Industrial Engineering, have joint efforts with the Tuscany Regional Council , the innovative startup and Pisa University spinoff ACAS3D Soluzioni Digitali and Foll.ia Lab to set up the artistic and technological installation Divina!

The project team included very heterogeneous skills (experts in Italian linguistics, engineers-topographers, specialists in the creation of installations and platforms for the use of digital content and in the production of creative concepts). The sciences and the arts involved have allowed many alternative interpretations of the installation, always with a view to celebrating the modernity of the *Divina Commedia* over the centuries.

"Divina!" indirectly puts the accent on a link between Dante and technology, often overlooked but nonetheless definitely recognizable throughout his opus, and also one of the elements that makes the Poem such a relevant work, still able to attract readers after 700 years and counting.

This installation provides food for thought on the importance of preserving and conserving, of keeping the roots in the path of evolution and innovation, in communication and dissemination. In this perspective, "Divina!" intends to lead users to think about the centrality that each person has in the growth of language, being themselves generators of disclosure.

For these reasons, the Authors have tried to replicate, in a contemporary key, the way in which the *Divina Commedia* has spread from the 14th century to the present day, from transcriber to transcriber, from person to person.

The goal was to reinterpret both the work and the poet in a digital reality, with a logic of play and immersive media experience, which would contribute to its dynamic interactive propagation: with the subtle irony of Dante's character, it is easy to imagine that, if the *Divina Commedia* had been conceived nowadays, it would most likely be a video game environment [Caroti et al. 2021].

"Divina!" encompasses transversal skills, the foundations of which were shared, with due philological respect, to make the spirit of all those involved in the project coexist in this installation.

A multidisciplinary working team was set up to achieve the objectives.

Andrea Piemonte and Gabriella Caroti coordinated the project through the ASTRO Lab. They supervised the digital encoding of the *Divina Commedia* and the development of the user interfaces, preparing the hardware and software for facial recognition and the design of the website dedicated to the installation.

Federico Capriuoli played the role of technical director and took care of logistics, thanks to his consolidated experience in managing multidisciplinary teams for the creation of installations and platforms for the use of digital content acquired through ACAS3D Soluzioni Digitali.

Marco Cisaria and Michela Belli were in charge of the artistic direction of the project, thanks to their experience in the production of creative concepts and artistic installations.

Giuseppe Patota, professor of Italian Linguistics at the University of Siena-Arezzo and member of the *Accademia della Crusca*, provided scientific validation of the compatibility of the artistic idea with humanistic aspects.

Artistic Concept

The *Divina Commedia* is one of the longest-lived and most widely distributed literary works in the world. To date, the work does not exist in its original form and, since it was produced before the invention of printing, it was transcribed by hand. Among all the man-

uscripts that have come down to this day there are many different versions. The cases of diversification are many and vary from simple orthographic changes, to complete distortions of the text.
The *Divina Commedia* has represented an innovative and dramatic vision of the contemporary reality of the time, managing to be both *COMMEDIA* and *DIVINA*, walking a thin line that divided fantasy and religion.
The work "Divina!" reinterprets the great writing of Dante, on the occasion of its 700th anniversary, bringing to the public a "metaphorical and artistic key" of what has arguably been the first collective poetic work ever made.
Divina! takes inspiration from the dynamism of the writing and from the diffusion that the *Divina Commedia* has had in the world, while also keeping in pace with the times. Based on this, the Authors seeled to replicate the way in which the *Commedia* has spread, from voice to voice and from hand to hand, transforming itself in a statuesque, dynamic and interactive work.

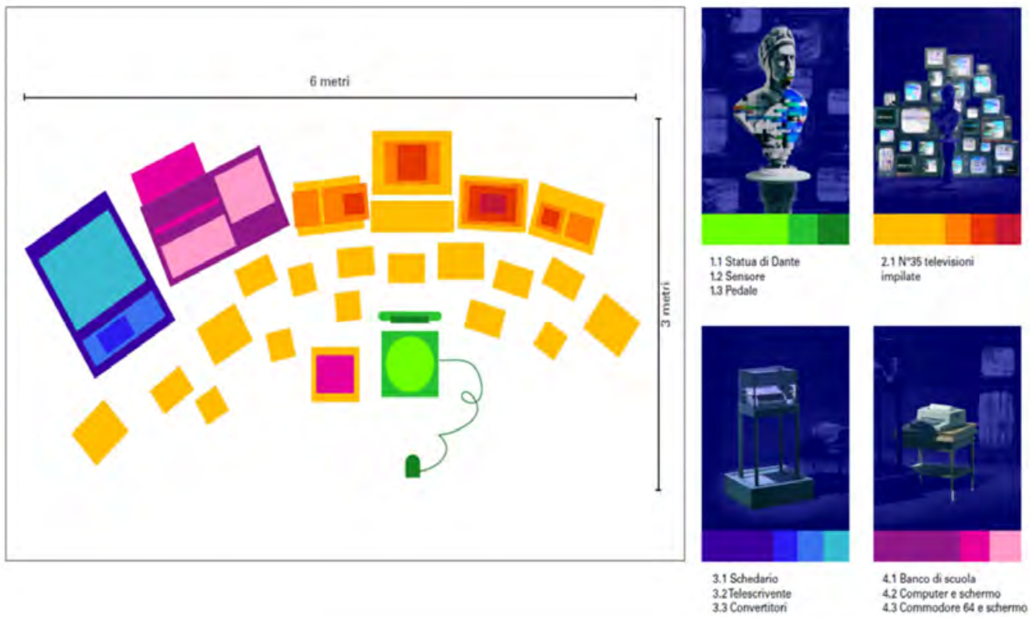

Fig. 1. Graphic concept of the installation DIVINA!

The "Divina!" experience was created to be installed in an indoor location open to the public and consists of a physical avatar of Dante that relates to a single user at a time.
The physical/analog avatar contains digital sensors that, through facial recognition, encode the face of users and transform it into a code, generating 3 lines of unique code, each corresponding to a portion of the face. The code of each portion is then processed by the avatar in order to make it correspond to a verse of the *Divina Commedia* digitized and properly encoded.
In this way, maintaining the tercet structure, a new tercet, built with three verses belonging to three distinct real tercets, is produced, corresponding to a mathematical elaboration of the users' face that, although with a surreal drift, retains its apparent poetic and "Dantesque" sense.
A printer prints the tercet on a sheet of paper for users convenience, and a teleprinter prints on a continuous form all the new unpublished tercets, recreating a new unpublished version of *Divina Commedia*
The experience lived in presence by users has also a reference to a virtual web environment where they can relive/continue their experience and where they have the chance to read or reread the cantos from which the single verses of their personalized tercet have been extracted.

Technological Component

The technological component is an essential part of the installation: users can witness the evidence of a century of communication systems that interact and converse, transmitting to each other pieces of the *Divina Commedia*.
Latest-generation technology used in the project includes an Intel sensor for facial recognition and a videogaming computer, whose processing and graphic performances are suitable for complex photogrammetric elaborations.
Next to this PC there is a computer mainly dedicated to video games of the '80s, the Commodore 64.
A series of cathode ray tube televisions from the '50s, '60s and '70s then serve as a temporal link to a teletypewriter from the '40s.
The signal generated by the contemporary Intel sensor is translated, sent and displayed by seemingly obsolete communication systems, thanks to their shared binary language roots.

Facial Recognition Sensor

On the market there are many solutions for facial recognition, starting from simple webcams up to more advanced and complex systems. The system included in Divina! uses the RealSense ID sensor, designed by Intel exclusively for facial scanning and boasting a recognition accuracy of 99.76% (Fig. 2). The sensor does not provide for storage of captured images. Its compact and lightweight design and form factor, which allows for ease and flexibility of installation, were evaluated as additional advantageous features [El Bouazzaoui et al. 2021; Li et al. 2021; Celakil et al. 2021].

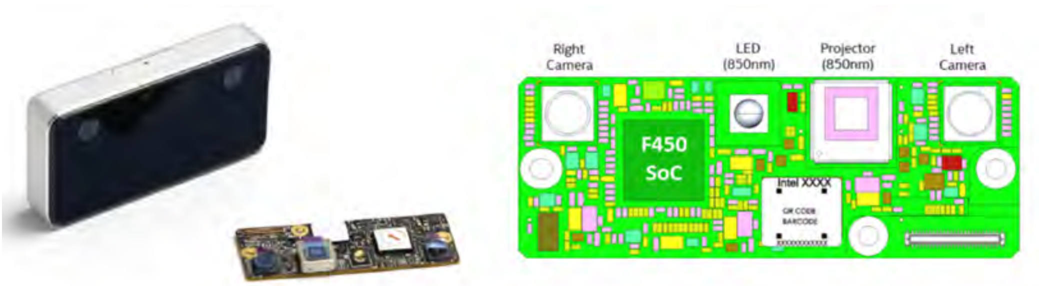

Fig. 2. Intel RealSense: sensor.

Intel RealSense ID uses a specialized neural network that utilizes input data from an active depth sensor. This neural network ensures accurate and secure facial recognition, thanks in part to its built-in anti spoofing technology, which ensures that no photos, videos, or masks can be used for recognition. The processing of the acquired data is divided into two phases. The first is the enrollment process, in which the device stores encrypted facial impressions on the database. A facial fingerprint is defined through mathematical and geometric modeling for notable points of the user's face. The second step is the authentication process, in which the device generates the facial fingerprint and compares it with all the facial fingerprints enrolled in the database. Finally, it returns whether authentication was forbidden or allowed with the enrolled user id.
Describing the sensor in more detail, it is composed of an optical system, consisting of two RGB cameras and an infrared (IR) emitter. The pair of cameras (HFOV 59°; VFOV 80°; DFOV 90°), thanks to the fixed grip base, allow a three-dimensional restitution of the acquired face. The infrared optical system includes both an LED to illuminate the scene in low light conditions and a regular pattern projector for 3D triangulation.
The coexistence of RGB and IR systems allow the sensor to work regardless of the type of lighting of the scene and without the need for a dedicated background. In addition, the

use of feed-forward type networks with supervised learning [Alemayoh et al. 2021] allows for operation even with no need for users to stand still during authentication and ensures a claimed repeatability of 99.76% in subject authentication. The hardware and the neural network are closed systems that cannot be modified in the design phase. It is possible, instead, to modify the user interface and to manage communications between sensor and PC. An ad hoc software interface has been built for the installation, which manages communications with users during the approach to the installation, the identification and the conclusion of the experience. Through the same interface, the unique code generated by the Intel sensor is used to generate the "Divina_ID", a 9-digit alphanumeric code. This code is generated by an algorithm that randomly selects from a digitized and encoded version of the *Divina Commedia* three verses belonging to three distinct tercets. Approaching the installation, the user is encouraged to repeat the experience multiple times so that the consistency of the unique face-tercet association can be verified.

Vintage Technology

As mentioned earlier, the installation complements the latest facial recognition sensor with vintage technology components. One of these is the Commodore 64 PC/video game console. The console was put in communication with the modern PC via the 24pin user port. In order to interface this oudated port with the USB of the PC it was necessary to build a special adapter that first converted the user port in a 9-pin serial and then in a USB (Fig. 3). It was then necessary to write two softwares to put in dialogue the two computers: one in C++ for the PC and one in BASIC for the Commodore.

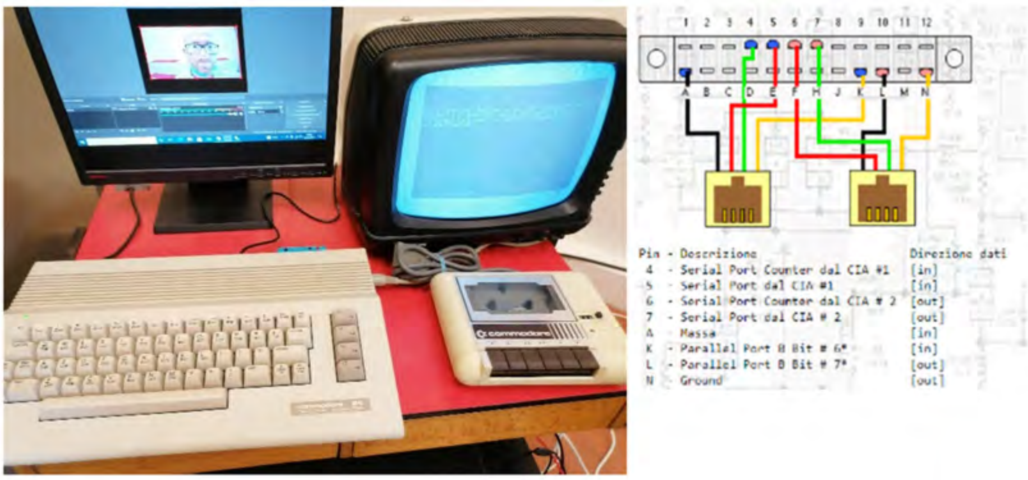

Fig. 3. Commodore 64 and 24 pin port scheme.

The new tercet assigned to the particular FaceID is thus transmitted from the PC to the Commodore and displayed on its screen and on the central television of the installation.
Since the Commodore is a computer of the '80s, the video output standard is already analog via RCA coaxial cable (in those years, computers frequently used a normal CRT television rather than a dedicated monitor). Therefore, it was not necessary to use a video format converter; otherwise, an intermediary is required to display an MP4 video file residing on a USB stick on all the other televisions in the installation. A media player reads the mp4 file from the stick and outputs video on HDMI format; an HDMI-SCART converter then acts as a conduit for an analog-to-digital converter with RCA output.
The representation of the last generational leap between technological components occurs with one of the most fascinating elements of the installation: the Olivetti teletypewriter (Fig. 4). It is an automatic electromechanical device for receiving and writing texts.

Fig. 4. Olivetti Teletypewriter.

In the first half of the 20th century, teletypewriters were widely used in radio transmissions of postal messages. They were also used extensively during the Second World War (as evidenced by the images in many films) because they were well suited to applying special encryption to messages.

The format in which the teletypewriter receives and sends a message is typical of radio transmissions and is of the audio type. A two-tone audio signal is sent through the headphone output of the sound card. This signal is transmitted on two distinct frequencies: 1496Hz on the main one with a 425Hz shift on the other. The baud rate is 50bd (equivalent to 60 wpm – transmission speed of words per minute). The transmission protocol is RTTY, which uses a so-called Mark & Space encoding. The desktop PC, where the new tercet is generated, sends an RTTY-compliant signal to the teletypewriter via the headphone output of the sound card.

To make the PC communicate with the teletypewriter there are two pieces of software that act as language mediators. The first, MixW, is used by amateur radio operators to manage service messages between the PC and the teletypewriter and to encode text messages. The second is used to automate the process, as MixW is designed to be used with manual text input by an operator. This software, written in Visual Basic, simulates a virtual operator by importing the text of the new tercet to be printed and executing the appropriate MixW routines.

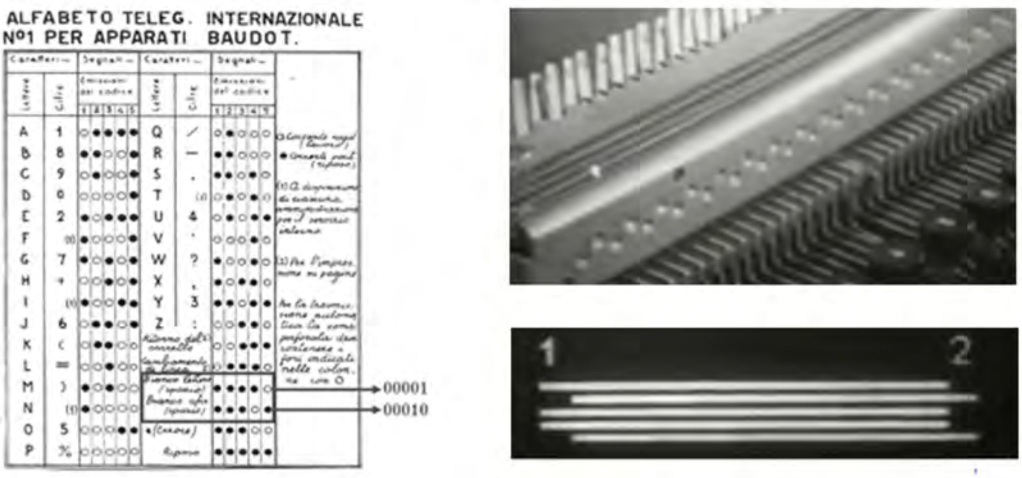

Fig. 5. Baudot alphabet and mechanical selection bars.

As regards the language used, Mark & Space coding is very similar to a perhaps better known language, i.e. Morse code. The packets of 0 (Mark) and 1 (Space) contained in the message sent (the alphabet used is the international 5-bit encoding called "Baudot") determine the movement of a switch into two possible positions: "Position 0" and "Position 1" (Fig. 5).
In the teletypewriter, the switch positions result in the movement of 5 toothed bars into 2 possible positions. The number of possible combinations of bar positions is 25, which corresponds to 32 positions: these correspond to the 32 possible characters that the teletypewriter is able to write for each position of the carriage (one for letters and one for numbers and symbols).

User Experience Conclusion

At the end of the use of the installation, users can retrieve from the printer their own personalized tercet with their own unique code with which it is possible to continue the experience on a dedicated web site (www.divina700.it). On this site, by entering their code, users can read the canto from which each verse of their tercet was taken (Fig. 6).
The installation thus becomes also a means to invite and encourage the re-reading of three, or possibly more, cantos of the *Divina Commedia*.

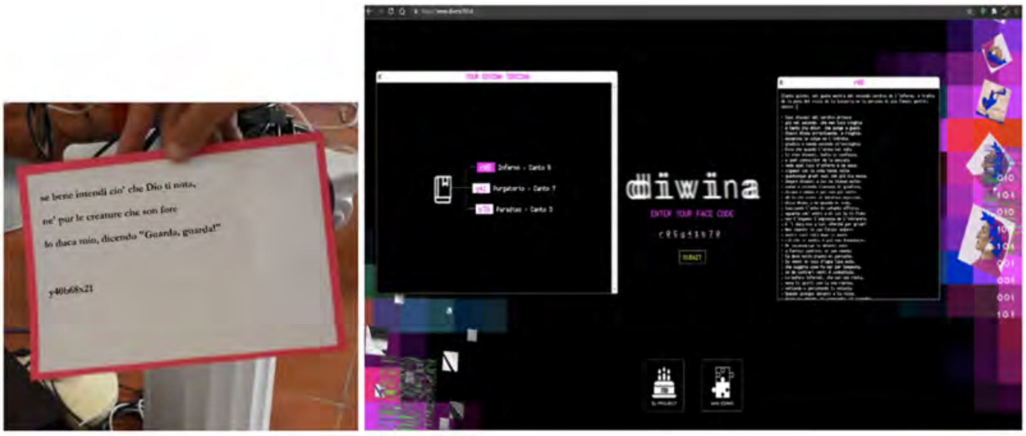

Fig. 6. Printing of the tercet and code for entering dedicated website.

Conclusions

The 700th anniversary of Dante's death will be celebrated and lived in the complicated context of the pandemic that has brought with it not only uncertainty, fear and suffering, but also an extraordinary impulse towards the digital transition. In the hardest moments of the lockdowns, the massive recourse to ICT-based solutions, from remote working to distance learning, e-commerce, etc., has shown us how digital technologies permeate almost every field of our lives in a pervasive way. The new technologies have supported the authors in the effort to recover a new condition of normality.
The project "Divina!" is placed in this context to celebrate the Great Poet and his immortal work by transposing the technological and digital reality in the Poem.
The *Divina Commedia* was written more than 700 years ago and has come down to our days without intermediaries other than those related to transcriptions or reprints of the text as it was.
Unlike the written text, technology needs many more processes of linguistic intermediation to ensure that the content created and usable on a given device remains so over time but offers the possibility to communicate and project the Poem into the digital future.

In conclusion, we owe a great deal of thanks to Dante, for writing a book seven hundred years ago, without which none of this would have been conceived.
Last but not least, a special thanks to culture and education, for still being able to excel today, as they surely will be tomorrow.

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AR&AI
Heritage Routes and Historical Sources

St. Nicholas of Myra: Reconstruction of the Face between Canon and AI

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Gianluca Lax

Abstract

This study is an ideal continuation of the one presented at REAACH-ID 2021. The results therein obtained are in fact the starting point for new evaluations and for the development of a protocol for the reconstruction of the missing parts in the Byzantine frescoes of St. Nicholas.
The research in question aims to carry out, thanks to Artificial Intelligence, digital restorations useful both for the formal and symbolic analysis of Byzantine iconography and for its communication to a wide audience. Four phases describe the research strategy: 1) choice of the case study and the field of investigation; 2) identification of the formal parameters in the processing of the paintings: canon; 3) definition of the work-flow relating to the work of artificial intelligence; 4) application of the study to a specific case and analysis of the obtained results.

Keywords
byzantine frescoes, effigies, inpainting, pyton, torch.

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Introduction

This study is an ideal continuation of the one presented at REAACH-ID 2021. The results therein obtained are in fact the starting point for new evaluations and for the development of a protocol for the reconstruction of the missing parts in the Byzantine frescoes of St. Nicholas.
The research is based on some preliminary considerations relating to the intrinsic qualities of Byzantine painting, its widespread diffusion in the Mediterranean basin, and the often unexpressed potential of the sites that host them. The iconographic structure of the Byzantine frescoes is strongly codified, it is in fact a perfect example of syncretism between the oriental aniconic matrix, centred on the decorative and calligraphic apparatus, and the western, Latin and figurative one. The Byzantine culture, spread throughout the Mediterranean basin, is one of the founding elements of our culture. Currently much of the religious and formal message underlying the Byzantine iconography is invisible, the causes, of course, are both physical and cultural. In fact, the state of conservation of the paintings prevents an evaluation while the absence of adequate cultural preparation does not allow the occasional user to appreciate the formal and symbolic contents of the works. The research in question aims to carry out, thanks to Artificial Intelligence, digital restorations useful both for the formal and symbolic analysis of Byzantine iconography and for its communication to a wide audience.
Four phases describe the research strategy: 1) choice of the case study and the field of investigation; 2) identification of the formal parameters in the processing of the paintings: canon; 3) definition of the work-flow relating to the work of artificial intelligence; 4) application of the study to a specific case and analysis of the obtained results.

Fig. 1. St. Nicholas of Myra: the scheme of 'three circle'.

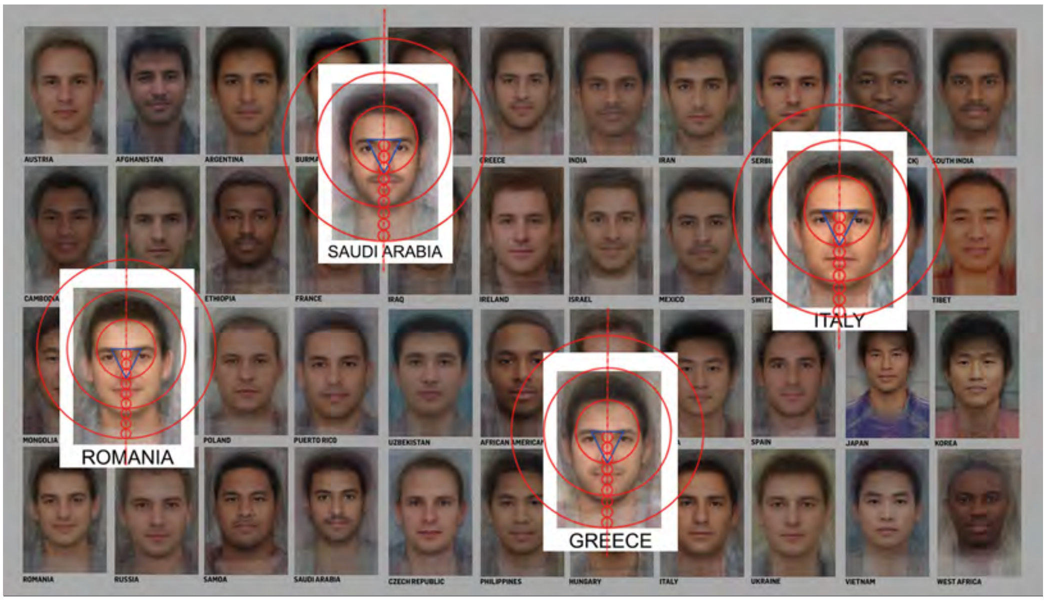

Fig. 2. Superimposition of the scheme of the 'three circles' to *The Face of Tomorrow* by Mike Mike.

The Case Study

The case study is the effigy of St. Nicholas of Myra, widespread throughout southern Italy. The iconography of the Saint, which is very repetitive and codified, lends itself well to an analytical investigation that involves the cross-comparison with omogeneous frescoes, in terms of technique and dating, belonging to the entire Mediterranean basin. The faces of the saints in Byzantine sacred iconography are rigidly defined by simple geometric figures and predefined proportional ratios. Using the results of the previous research we try to verify if the analysed examples respect the established canons, and if the latter can be used for the reconstruction of the missing parts.

Canon: the Formal Parameter

The search for a canon in the proportions of the human figure runs through the entire history of visual art even if, in various eras and in different cultures, it has taken on very different connotations. In fact, the canon can trivially express the search for anthropometry, or indicate the metaphysical structure, invisible and immanent, in the proportions of the human body; finally, the canon could be a simple technical support for the artist: a regulatory layout. In ancient Greece, the canon aimed at identifying the ideal dimensions of the human figure. The first of which we know is that of Polykleitos, Κάνον, elaborated in 450 BC, which had an enormous resonance in Western classical art and of which we have traces only from hints in later works. The Canon of Polykleitos while aspiring to verisimilitude, to the profound mimesis of human features, left room for the artist to freely compose its work by offering a system of proportional relationships based on ordinary fractions.
The practical theory of proportions, in the Renaissance, recovers the classical notions of Polykleitos and Vitruvius and makes them the rational foundation for the search for beauty. The canon in this historical period combines microcosm and macrocosm, geometry and matter. Finally, the canon can be aimed at the 'technical' realization of the work, in this case it is a structure that simplifies the tracing operations and gives a guide to the artist. An exemplary case is the grid that the Egyptians made before tracing the work. The grid, which divided the human figure into 18 or 22 modules, was used to construct the representation by giving the right proportional ratios to the parts. In the Middle Ages, the theory of Byzantine proportions abandoned anthropometry and mimesis while not completely denying classical art. Proportional schemes are no longer expressed as ordinary fractions and complex relationships

between the whole and the parts but with a schematic system of modules or the so-called 'system of unity'. The relationships between the parts of the body, or of the face, are defined by a rigid system based on a single module repeated a whole number of times. Sacred Byzantine art, more than the others, follows strict protocols in the tracing of the figures, probably to mark the separation between the real and the divine and to respect the multiple canons deliberated in the councils. Sacred icons, in fact, are intended as images of the Image, types of the Archetype, do not aspire to mimesis but are proposed as a gateway to the divine.
The identification of the rules underlying the 'Byzantine canon', among the scholars of the sector, is the philosopher's stone of knowledge, capable of extracting the 'truth' about the morphology and meanings of Byzantine painting. For this reason, over time, many scholars have been dazzled by manuals and texts of dubious origin. One of the most striking cases is that of Adolphe Napoléon Didron who accepted as authentic, that is, as a rewriting of a twelfth century text, the nineteenth-century manual of the painter Dionisio da Furnà [1].
Panofsky was one of the first scholars to highlight the rigid formal-symbolic and geometric rules underlying the creation of the icons and, in the famous text The meaning of the visual arts [Panofsky 1999], takes up the theories of Furnà and the so-called 'scheme of the three circle'.
The scholar identifies a concentric structure based on the size of the nose [2]. The construction tested on some examples provides the length of the nose as a unit of reference, which is divided into three parts and is the module of the entire composition. The smaller circumference at the base of the nose envelops the face with the exception of the lips. The second circumference, twice the size of the first, marks the size of the head and laps the chin. The third defines the nimbus (halo) and the position of the dimple at the base of the neck.
Panofsky in a note [Panofsky 1999, p. 84] underlines how the scheme is sometime applied in a partial way and that it is often generated by circumferences with a ratio equal to 1/1 ½ / 2 ½. In many cases the outermost circumference, the one that defines the nimbus, is not concentric to the others and wraps around the beard.
Before applying the canons identified by Panofsky, and then taken up by many other scholars, it seems interesting to us to check whether the proportions identified, for example, respect the anthropometry of a human face. After all, Vitruvius in his De Architectura already encodes the proportions of the human face and divides the height of the face into three equal parts marked by the length of the nose: "For the height of the face itself, however, it is one third from the tip of the chin up to the lower part of the nose, likewise measure the nose from its lower end to the end in the centre of the eyebrows; from this end to the lowest roots of the hair, where the forehead is formed, it is likewise a third" [3].
The sharing of data, in recent years, has made possible the morphological analysis of faces and, through artificial intelligence, automatic recognition. We can superimpose the 'three circles' pattern on the 'average face' of the different nationalities [4] and verify that the division of the face into three parts is the norm. Instead the second circle rarely describes the ridge of the head, even if a certain coincidence is noted in the Greek and Romanian faces; the outermost circle identifies, in the examples cited, also the dimple at the base of the neck.
The 'Byzantine Canon' is all too rigid and in fact it is denied by Panofsky himself who, in a note, underlines how the scheme he has taken up is often disregarded or applied in a partial way. In fact, circumferences often have a ratio of 3/4 ½ / 6 ½.
In many cases the outermost circumference, the one that defines the nimbus, is not concentric to the others.
By superimposing the scheme of the 'three circles' on the effigies of St. Nicholas (Fig. 3) we can verify that there is not a perfect correspondence but that most of the paintings oscillate, with variations equal to half a module, around the Canon: graphs marked in red, blue and yellow. The effigies characterized by the graphs in green have the second circle very close to the first with a ratio of 3/5/8. Finally, the effigies with the gray graphics are missing by some circumferences.
The verification carried out by superimposing the results of the division into clusters [5] on the rule of the three circles shows a certain persistence of the effigies analysed in cluster 1. Furthermore, the division into clusters is shown in Fig. 5 where the rule of 'three circles' is further verified by exemplifying the faces through the control points used for recognition.

Fig. 3. Superimposition of the scheme of the 'three circles' to *the AI Data.*

The AI restore

The approach we use to restore the digital representation of the effigies of Saint Nicholas is inspired by generative adversarial networks.
In machine learning, a generative adversarial network (GAN) is a technique in which two neural networks are competitively trained to reach a goal. One neural network is named generator, the other is named discriminator. The goal of the generator is to produce new samples to fool the discriminator, whereas the discriminator needs to detect if a sample is real or generated by the generator. This technique was first introduced in *Generative adversarial nets* [Goodfellow 2014] where the models of both the generator and the discriminator were multilayer perceptron.
The training procedure of the generative model aimed to maximize the probability of deceiving the discriminative model, which is equivalent to minimizing the likelihood that the discriminator performs correctly. The training procedure of the discriminative model aimed at maximizing the probability of distinguishing real data from generated samples. At each iteration, the generator knows the classification done by the discriminator and uses this result to produce new samples. A schema of how a generative adversarial network works is reported in Fig. 6.
Generative adversarial networks are used in many application contexts such as image dataset enrichment, generation of human faces or cartoon characters, text-to-image translation, face aging.

AI Workflow

The artificial-intelligence-based technique used to restore the digital representation of the effigies of Saint Nicholas has been implemented in Python and exploits Torch [http://torch.ch/], an open-source library for machine learning.
The limited number of effigies of Saint Nicholas available in our study does not allow us to train a model. For this reason, we decided to start with a pre-trained model for human faces, then we customized it with the effigies of Saint Nicholas. Since the model works with low-resolution images, another AI-based post-processing task was exploited to increase image resolution. Specifically, the adopted workflow is composed of the following steps.

1. Input management. The available set of images of San Nicholas to be used as input is shown in Fig. 7. The set is composed of eighteen 1690x1690 pixel images having the same size. Among these images, we have selected those that have very limited parts to be restored and these images are used to customize the generative model.
Moreover, we selected the image in the worst state of conservation and used it as the input of the process of restoring. The image to be restored is reported in Fig. 8 a along with the "mask" to be used for restoring, which is a 2-color bitmap image having the same size as the other inputs and black pixels in correspondence of the parts of the image to be restored (see Fig. 8 b).
2. Generation. The limited size of the input images is not sufficient to train the generative model. For this reason, we used a standard approach consisting in finding a model already trained for the same purpose and then customizing it for the specific scenarios with the available effigies of Saint Nicholas. The model we used in this phase is generated by a deep fusion network [Hong 2019] and requires two inputs: the image to be restored and the mask (Fig. 8 c).
3. Upscaling. Training a model with high-resolution images takes a lot of time, thus the model training has been carried out by 512x512 pixel images. As a consequence, the generated output has the same (low) resolution as the input. In this step, we use a deep convolutional neural network trained on a large set of general images (i.e., different from the effigies of Saint Nicholas). At the end of this step, the size of the generated image is the same as the initial input, and the result of the elaboration is reported in Fig. 8 c.

Fig. 4. The rule of the three circles superimposed to the division into clusters.

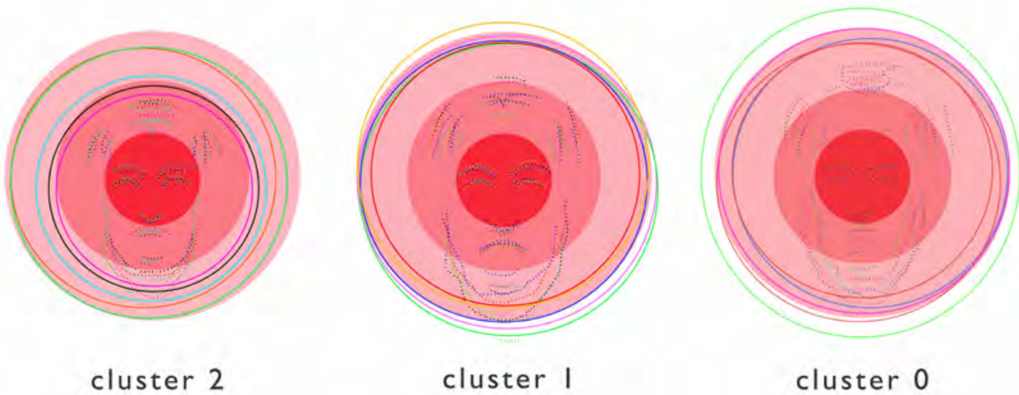

Fig. 5. The rule of 'three circles' verified by exemplifying the faces through the control points.

Conclusion

The comparison between the original effigies and the restored one shows a great improvement. In particular, the small missing part on the top of Fig. 8 b has been completely restored. The large strip in the middle of the effigies has been partially restored, in particular in proximity of the missing eye. However, large parts missing are much more complex to be restored than smaller ones.

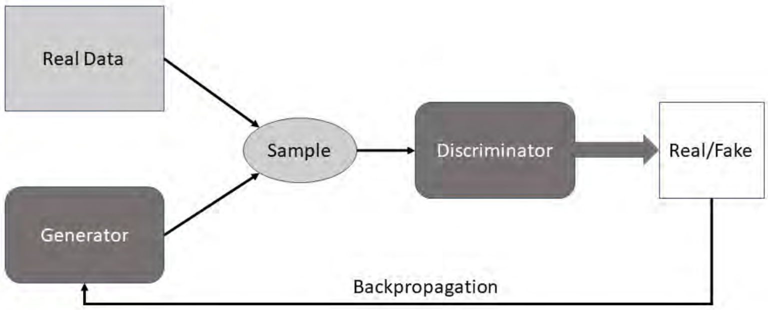

Fig. 6. AI workflow.

Fig. 7. The available set of images of San Nicholas used as input.

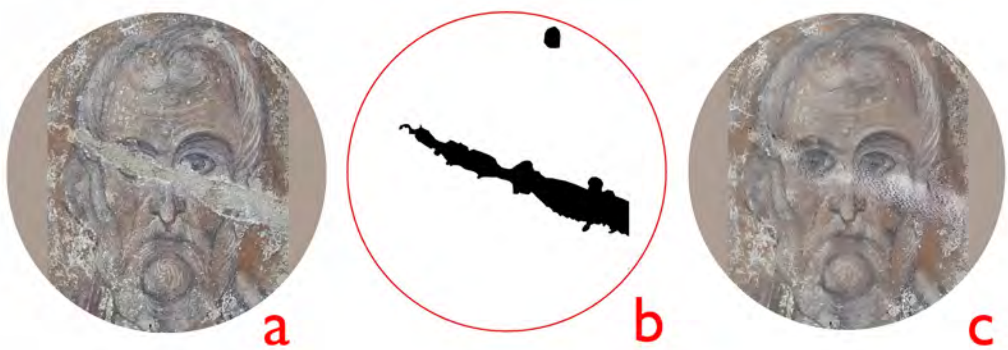

Fig. 8. The reconstruction of the face of St. Nicholas of Myra through the AI.

The model obtained with AI could show the missing parts of the saint's faces and be of support for the reconstruction of other effigies not belonging to this research. The results of the reconstruction may be useful for the creation of a database for enriching the documentation of the Byzantine iconographic heritage and for the development of content for new media. The enhancement of the asset, in fact, always rests on a double track: on the one hand the philological and scientific reconstruction of the iconography and on the other the communication of the underlying cultural and formal matrices.

Notes

[1] This is the story of a false medieval Byzantine manuscript, recognized as such since the beginning of the 1900s and which even today some people persist in passing off as true. In 1839 Adolphe Napoléon Didron went to Greece to study the works of art of the Byzantine age. And there, wandering among the monasteries of Mount Athos, he was able to observe a guide to artistic making, whose author (the painter Dionisio da Furnà) provided indications on the technical measures to be followed and on the iconographic characteristics to be respected. Didron believed he had come across a manuscript which, although compiled in the century XV or later, it reported rules and behaviours from a much older period, dating back – as the monks of the place claimed – to the 10th or 11th century, that is, to an age that has recently emerged from the well-known controversies on the lawfulness of the use of images. (See Dionisio da Furnà, Hermeneutics of painting, Edited by Giovanna Donato Grasso Introduction by Sergio Bettini, Fiorentino publisher, 1971)

[2] The circular structure is an aid for the artist without being the necessary condition of the design. In the end though, the structure shows itself as the mysterious ground of the icon's harmony. […] the first circle which has the radius of the length of the nose creates the space for the eyes and the forehead. The circle whose radius is two lengths of the nose determines the volume of the head. The halo, by contrast, does not correspond to the third circle but is displaced toward the bottom because it encircles both the beard and the hair and must be inscribed in the format of the icon.

[3] VITRUVIO, De Architectura libri decem, (curator Curt Fensterbusch), Darmstadt 1996, III pp. 91-92.

[4] The base image of Figure 2 is taken from the 2011 project "The Face of Tomorrow" by South African Photographer Mike Mike who collected the faces of people from various cities for a studio at Goldsmith University in London.
In 2004, the Korean artist Atta Kim in his ON-AIR Project, Self-Portrait Series, 100 Countries / 100 Men had already created the image of an average face.
Effectively, in 1880 Sir Francis Galton, cousin of Charles Darwin, was the first to create the image of the "middle face" by superimposing multiple portraits of individuals.

[5] The subdivisions into 'clusters' referred to in this paper refer to the results obtained with the research carried out in the context of the REAACH-ID 2020 conference [Arena Lax 2021].

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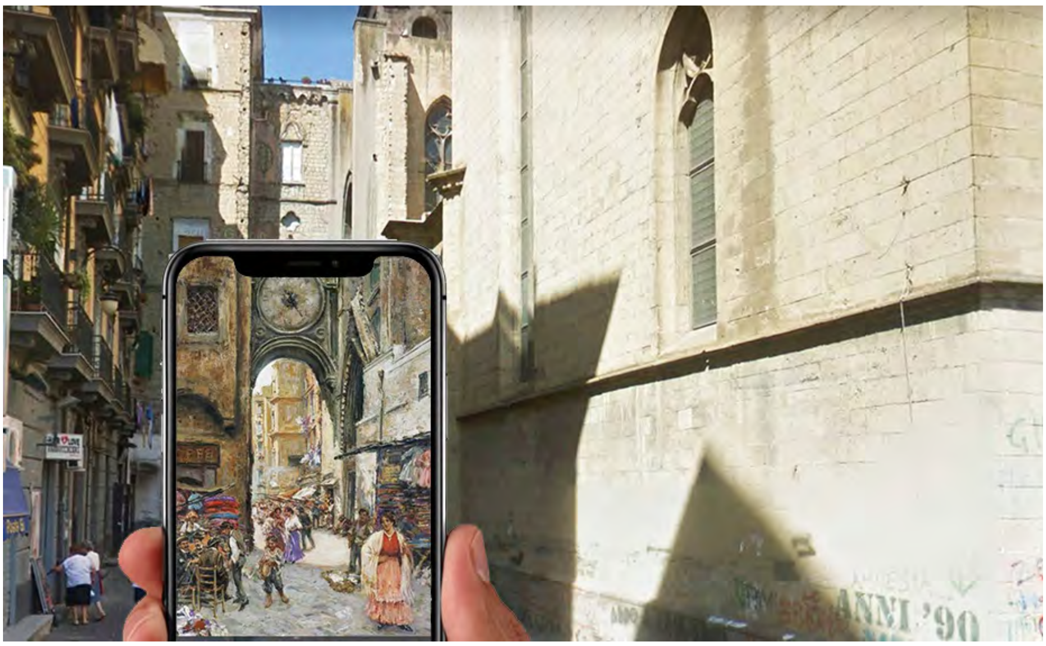
Perspective Paintings of Naples in Augmented Reality

Greta Attademo

Abstract

With this contribution we intend to continue a research started in a previous study on the construction of a narrative strategy to communicate the pictorial images of historical cities. Resuming the theoretical and cognitive process started previously, which directed the research towards the construction of a geocoded map of urban paintings and their use in augmented reality, we now intend to validate the proposed methodology on the pictorial image of Naples, chosen as a case study application, identifying weaknesses and strengths of the research process and its possible future directions.

Keywords
ICT, AR, geocoding, perspective paintings, Naples.



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Introduction

Information and Communication Technologies (ICT) play an increasingly decisive role in our society. Their constant evolution and involvement in every aspect of daily life have contributed over the last twenty years to a paradigm shift in the modalities of knowing and experiencing the world. The intertwined dynamic between humans, digital artefacts and outside world has produced an 'intercategorial fusion' [Simondon 2014], changing the symbolic structure of the human cognitive and informative system [Asensio et al. 2010]. As Gianfranco Pecchinenda observes, «contemporary man considers himself a material entity predisposed to receive, process and communicate information with an external reality composed 'indifferently' of entities similar to himself, or of purely immaterial entities» [Pecchinenda 2010, p. 128]. In a world where atoms and bits tend to contaminate each other [Mandelli et al. 2011], important issues and new challenges also arise for the communication of the Cultural Heritage. Today's public needs new communicative strategies to perceive the cultural traces contained in the Heritage itself, which would otherwise risk remaining silent without subjects able to perceive and interpret them [Toscano, Gremigni 2008]. Therefore, we asked ourselves what role the representation could play in the construction of a communicative action able to emphasise «the invisible information which any artefact conveys per se, beyond the mere material dimension» [Bergamo et al. 2016, p. 3]. Representation, in fact, by embedding meanings in a visual system of signs, has always constituted a universal communicative language usable in the interpretation of the operative relationship between man and world [Maldonado 2015]. In particular, this research investigates representation as a tool to increase knowledge of cities, using paintings with urban scenes in a new narrative key. City paintings, being visive documents of a specific era, contribute to the construction of a permanent visual memory of the urban organism which, by its nature, is dynamic and changing [Socco 2000]. Often, paintings of the city allowed academics to formulate architectural hypotheses, identify the relationship with the landscape or even understand the places considered most significant in a specific historical period. It is true that painters have often made use of imaginative components in order to mask the city's weak points, recreate ideal harmonies or balanced pictorial compositions, but, in Laura Carlevaris' words, «if in representing [...] so many illustrators and engravers have felt the need to narrate the invisible, perhaps this invisible has actively participated in the consolidation of a more complex image, certainly, but no less persistent, effective and in any case inescapable» [Carlevaris 2014, pp. 29-30]. In other words, artists have always been able to propose their own vision of the world, often linked to the cultural and social imagery of their time. The pictorial drawing of the city, therefore, even if filtered by an artistic interpretation, constitutes a valid instrument of knowledge and communication, not only for those who use the iconographic apparatus as a documentary source for studying and planning space, but also for society itself which, through the paintings, can receive those perceptive-sensorial data, not extrapolable from purely objective sources, linked to relationships, events and uses of urban spaces. The value of these paintings, therefore, does not end with their conservation, but is expressed in their ability to give people a greater awareness of the space in which they live, of its past and future setting.

Case Study

This research develops as a natural continuation of a previous study on the use of representation as a narrative tool for urban metamorphosis [Attademo 2020]. The previous study was launched in 2020, during the lockdown period which, due to the pandemic emergency, had 'forced' cultural institutions to close. This dramatic event, which still partly affects us, has encouraged cultural sites to build a new virtual relationship with the public. There has in fact been an acceleration in the digitalisation of cultural content, a factor that has certainly contributed to the dissemination of culture with no space-time constraints. However, what has often been lacking is a rethinking of the way in which cultural content

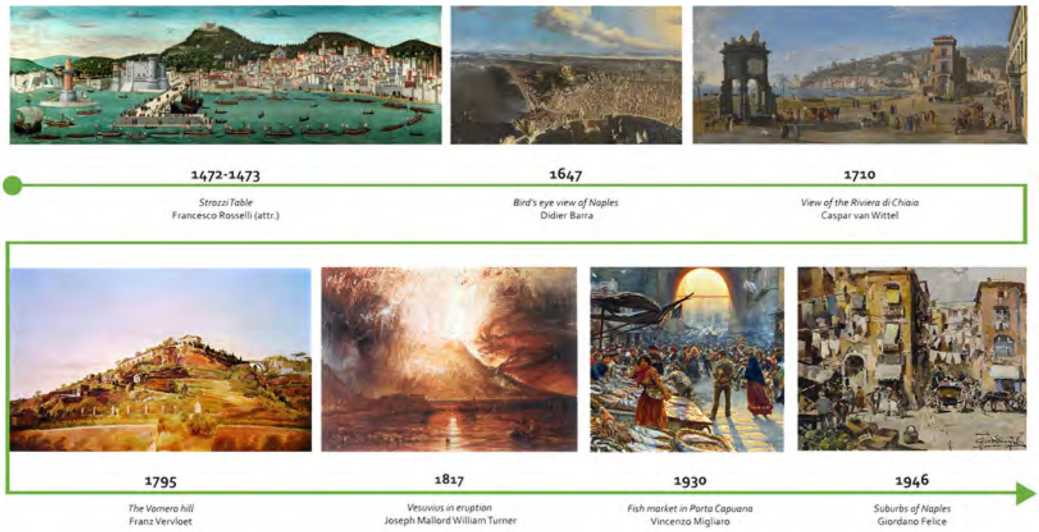

Fig. 1. Evolution of the urban pictorial image of Naples.

is narrated. The communicative language has rarely been intended as visual storytelling; by re-proposing exclusively analytical, typological and descriptive approaches in the virtual, the gaps and weaknesses already present in the communication strategies of the physical places of culture were revealed. This led us to hypothesise a strategy for narrating the pictorial images of historic cities, through the construction of a geocoded map, within which we could locate certain pictorial views according to the point of view taken by the painters, connected to an augmented reality app that would allow the overlapping of the painting with the real urban context. The present research intends to activate the experimentation of the method proposed in the previous study, expanding the cognitive and theoretical process at its basis. We believe, in fact, that the methods used to deal with the effects produced by the health emergency should not only be considered as temporary solutions, but also as the way towards which the communication strategies of the 'future normality' are directed. The aim is to validate the methodological process by applying it to an experimental case study in order to identify weaknesses and strengths of the research process. The goal is therefore to verify if the narration of paintings through new technologies can increase the intrinsic capacity of cultural heritage to «arouse emotions, establish connections, awaken curiosity» [Paolini et al. 2005, p. 51]. The city chosen as a case study is Naples, whose image, over time, has been strongly conditioned by the various political dominations and cultures that have followed one another uninterruptedly (Fig. 1). Moreover, Naples has maintained a central role in the figurative arts for centuries, becoming not only a centre for the development of pictorial movements, but also a focus of interest for artists who, depending on the dominant features of their era, used different languages, methods and techniques to represent it. The numerous paintings depicting Naples symbolise those urban signs and meanings that the artists were able to capture and crystallise in images in order to stimulate the interest and curiosity of observers.

Research Methodology

Narrating cultural heritage to a non-specialist audience means creating a balance between the scientific principles of representation and today's narrative strategies. Contemporary communication, influenced by social media, Internet and video games, is increasingly abandoning the passive transfer of knowledge and moving towards participatory forms of meaning-making by the user. In order to understand urban paintings, the viewer will be all the more motivated the more he is able to independently create a relationship between them and the contemporary city. Comparison allows differences and changes to show themselves more clearly to the unskilled observer. Therefore, for the Naples project, we chose to narrate paintings whose urban image is constructed through the perspective method. This choice derives from the fact that perspective produces images that are «verisimilitude [...] that translate into the plane the third dimension which the paper support (or at least the two-dimensional one) is obviously lacking» [De Rosa et al. 2001, p. 5]. The ability to transcribe the appearance of forms on a flat surface [Kemp 2006], means that the viewer can understand that communicative code (*perspectiva artificialis*) even without knowing its technical-scientific rules, because he has already assimilated it through his own visual experience (*perspectiva naturalis*). In these images, moreover, the view «places the eye of the observer of the perspective in the centre of projection used to construct it [...] When the observer assumes this position, his vision of real space and his vision of the graphic, two-dimensional perspective of that space collide perfectly» [Carlevaris et al. 2010, p. 142]. The observer in front of the perspective painting represents the centre of the construction, taking the place of the artist and thus becoming himself the creator of the spatial image: this feature is very appropriate to the participatory and interactive expectations of the contemporary user. In the experimentation, the decision to overlap the paintings on the actual urban scenario imposed the need to consider some elements of the perspective representations as binding. The height of the artist's point of view must correspond to the average height of a man, so the centre of projection on the plane of representation can be adapted to the points of view that today's observer can assume in real views. The observer's position must also be findable in the urban walks that the contemporary city allows. Finally, the distance between the observer and the object must be respected, so that the pictorial and physical scenery can overlap. In order to satisfy the parameter of viewpoint, only paintings in perspective with a vertical plane were selected for the experiment on Naples. The perspective of many paintings has been analysed, by recreating the painted space using the inverse procedure of conical linear perspective. The internal reference has been identified starting from the main point Vo, orthogonal projection on the plane of the observer's point of view V. The horizon line has been identified as the place of intersection points of the horizontal lines perpendicular to the plane, while the fundamental line has been placed coinciding with the lower limit of the painting. The observer's position has been identified through the distance circle with the radius VoV*, where Vo belongs to the horizon line and V* corresponds to the point of view overturned on the frame [Pagliano 2005, p. 42]. The observer's position in paintings is also recognised through the analysis of documentary sources, specific references in the title or description of the painting, or identified through specific architectural or natural features (Fig. 2). This was then searched in the current image of Naples through Google Street View, a tool that allows a virtual exploration of the city through a representation obtained from the composition of millions of panoramic images. Therefore, 19 paintings with the above characteristics were selected from the large repertory of pictorial images of Naples to constitute the first collection for experiment (Fig. 3).

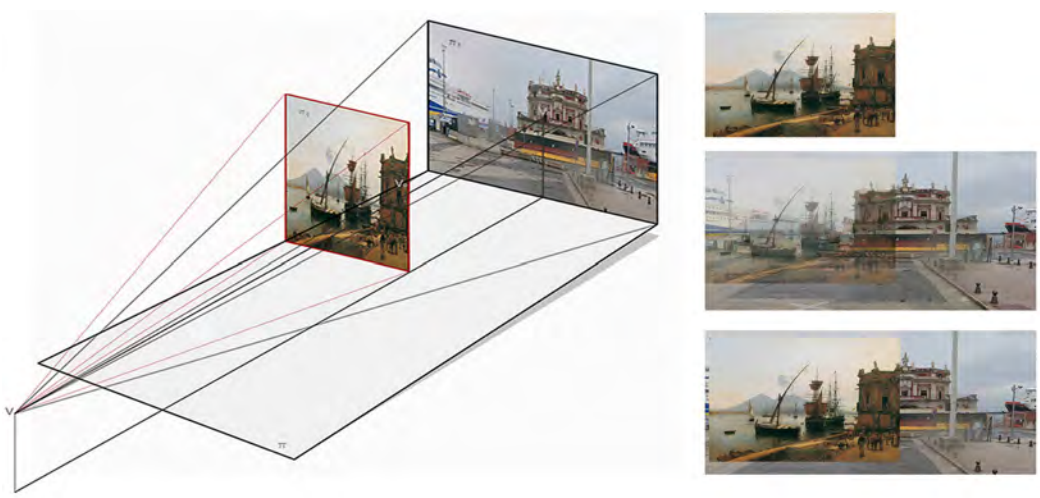

Fig. 2. Perspective analysis of paintings of Naples and superimposition on the contemporary urban image.

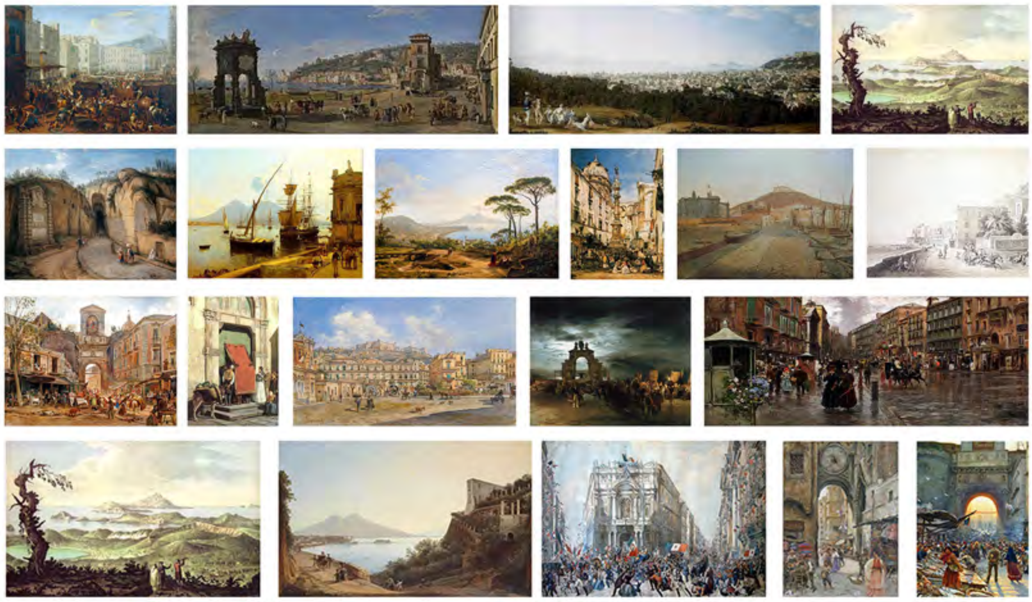

Fig. 3. The collection of 19 paintings chosen for the experiment.

The points of view depicted by the painters in their Neapolitan views are inserted into a geocoded map (Fig. 4). This is constructed using MyMaps, a free and accessible Google tool that allows maps to be customised, adding points of interest, multimedia and text files. This tool was chosen because, by simulating the graphics of the better known Google Maps, it allows for greater recognisability and ease of use by the user that has only the task of accessing the preconstructed map and virtually exploring its contents. The map, however, can always be modified by the designer, ensuring that the narrative can be reorganised and implemented. The map is structured on a fixed layer, the current cartography one, to which pins are added to identify the position of the different paintings according to the point of view taken by the artist in the perspective representation. The overall reading of the map is facilitated by the presence of labels, each related to a pin, allowing the observer a user-friendly navigation, which allows him to recognise points of interest without the need to digit their geographical position. Each label is linked to two images: one relating to the painting, implemented by information on the author, the year of creation and the pictorial technique used; the other, showing the corresponding perspective view in real space, first identified on Google Street View and then captured by positioning oneself centrally in it, in order to remove the perspective distortions typical of wide-angle images.The map constitutes only the first level of knowledge of the imago urbis that, in order to be perceived, requires the observer to become part of the narrative through his mental and visual capacity. Implementing the narrative of a painting is a complex operation, because the painting itself is the result of the artist's interpretation; for this reason, it is the pure observation that provides a more objective narrative of the artwork, since the viewer can put it back into the present, interpreting it and making new associations. Moreover, the bombardment of images to which we daily are exposed has considerably reduced the attention threshold of the public [Manovich 2001]; The observation of the pictorial image, therefore, can be implemented by enriching its sensory perception, allowing it to capture the public's curiosity and interest. Considering that «movement is the strongest visual appeal to attention» [Arnheim 1974, p. 372], the research chooses Augmented Reality as a narrative strategy. This technique, by allowing a new visual layer to be superimposed on the existing physical space, can enrich the ways in which people experience the city. We choose Artivive, a free augmented reality app, using views of the current urban scenario as markers, i.e. as images that the technological device will have to recognise to activate the virtual content (Fig. 5). Once the marker is framed on the mobile device, in fact, some video clips are activated showing the current urban image on which the corresponding painting image is slowly superimposed. In the previously constructed clips, the perspective

Fig. 4. The geocoded map of pictorial Naples.

of the paintings is superimposed on that of the images of the contemporary city already present in the map (Fig. 6), using a central position to further obviate the possible marginal aberrations of wide-angle views. Once overlaid, the views are cropped, so that only the perspective-corrected visual elements are preserved. By activating the augmented reality content, the observer becomes an active part of the narrative, recognising, in some cases, the transformation in the use of spaces, through the superimposition of narrative local history scenes on the daily background of the city, in others the different perception of places, through the comparison of colours, tones, lighting and urban relationships.

Research Results And Future Perspectives

The experimentation of the method on the case study of Naples allows to evaluate strengths and weaknesses of the communication strategy. The construction of the geocoded map permits the combination of cultural narration with today's intelligent geographic information systems, which are widely used in the virtual knowledge of urban places. Although art mapping systems already exist, they generally indicate the place where the artwork is displayed, and not the place represented in the painting, which is an innovative and original factor in the city's narrative. The geocoding of the paintings transforms the map not only into a digital database that can be continuously consulted and implemented by scholars, but also into a new interactive cultural portal that can be easily used by citizens. This model of use, following playful and recreational learning mechanisms, allows for greater cognitive accessibility to cultural heritage, especially for those sections of the population that do not find themselves in the classical methodologies of culture transmission. However, the preliminary research regarding the paintings to add to the map and their perspective analysis have required a long and careful bibliographic and iconographic study.In the future, the construction of specific software using artificial intelligence to process the geometric data of the painting, such as the height of the viewpoint and the position of the observer, would certainly speed up the analysis processes and expand the number of paintings mapped. As regards the use of the paintings in augmented reality, the strengths are certainly interesting. In fact, augmented reality is a versatile and easy-to-use tool, becoming a privileged instrument for communication to the non-expert public. The user becomes not only a viewer, but also an agent of knowledge. The opportunity to superimpose a new level of information on the physical space can contribute to change the user's impression of urban contexts: by exploring not only the spatial but also the temporal dimension, the user builds a dynamic city image through its stories, customs and perceptions. In technical terms, the experiment is exclusively virtual. The activation of the augmented content, in fact, takes place by framing from a mobile device a photographic image contained in the map, that shows a place in the physical urban space. This image, being digital, is immediately recognised by the Artivive app, allowing the activation of the augmented content. It would be interesting, in a future application, to transfer the same methodological processes in a project that could combine augmented experience and real physical space. We could imagine, in fact, the insertion of some information poles in urban

Fig. 5. Activation of augmented reality content through the Artivive app.

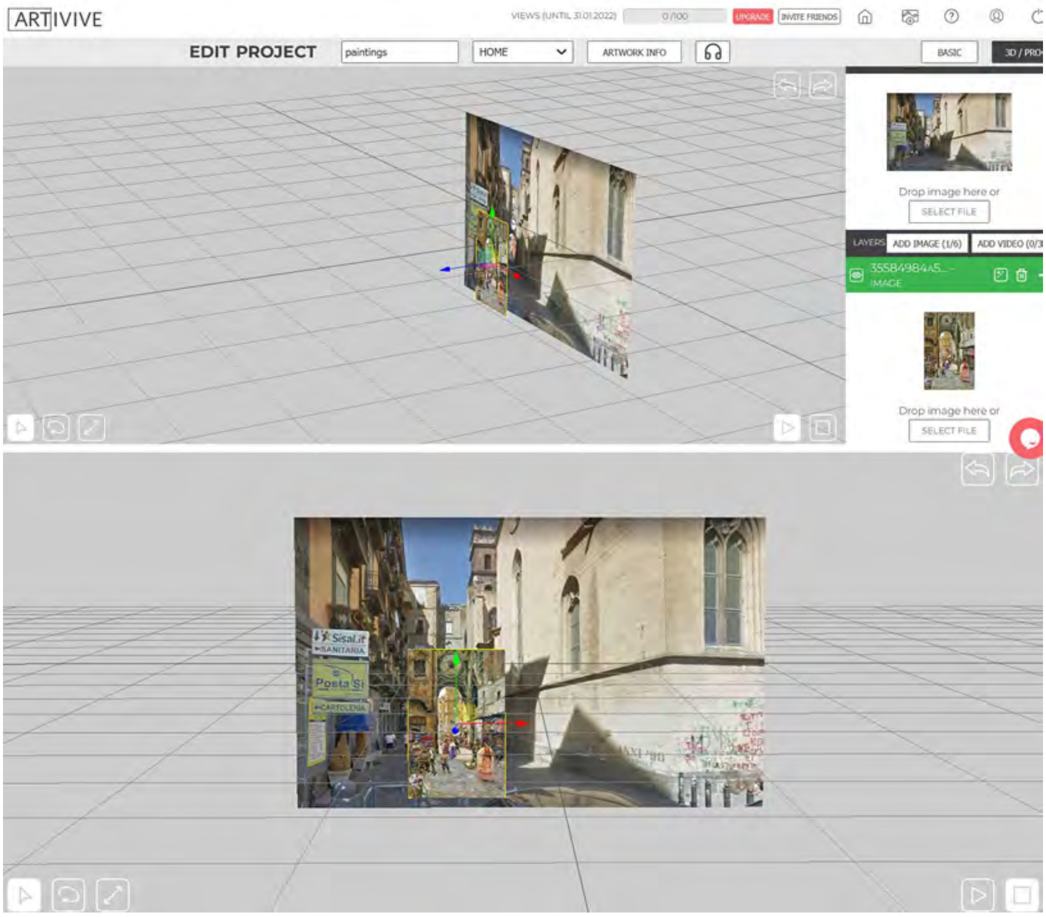

Fig. 6. Construction of augmented reality content by superimposing the point of view of the painter and that of the contemporary observer.

places showing the presence of an augmented reality content. The user, being close to one of them, would follow the instructions to download the Artive app. By framing the portion of the city with his smartphone, the latter would become the marker to be recognised. This would allow the painting to be superimposed on the urban reality and not on a digital image of it. Although this process is much more complex, because it would require detailed studies and experiments on the factors for the recognition of the marker (light effects, presence of objects, movement of people, etc.), it would allow the creation of a real phygital experience, thus transforming the city into an open-air augmented museum. The experimentation carried out in Naples, however, shows how the conscious choice of technologies and their combination with scientific studies can contribute to increasing the knowledge of the city: the physical one, to which historical and artistic information is superimposed through augmented reality, as well as the represented one, whose point of view is provided in relation to the real space through the geocoded map.

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Augmented Street Art: a Critical Contents and Application Overview

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Abstract

Street art is a growing phenomenon. The frequent appearance of works, projects, and events in this area reveals its increasing social and cultural role worldwide. The chance of digitizing art represents a benefit to defining cultural paths on the territory, providing an additional tool to understand and interpret it. Street art is characterized by peculiar aspects that make it unique in the artistic panorama. The democratization of contents and the physical decay of the work are two pillars. Any digitalization and communication project should consider them carefully, proposing a knowledge model respectful of the art. Augmented Reality (AR) is a representation tool that leads to achieving that delicate balance between the real and the digital, enhancing the specificities of both. The authors start from the experimentation about artwork digitalization, connecting image deterioration with image recognition. Besides, they show some possible applications in Rome through a critical analysis of the domain, opening some future multidisciplinarity scenarios.

Keywords
street art, impermanence, marker tracking, content connection.

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Introduction

Street art, considered as a free graphic representation of artistic subjects on vertical or horizontal surfaces, is experiencing a moment of a global renaissance. These representations, which characterize the urban scenes, belong to everyone: creators, citizens, tourists, critics. It is an art without boundaries, free from museum routes but limited in protection and affiliation [Balocchini 2012]. Street art has different goals. On the one hand, it wants to enhance degraded urban areas and architectural structures, introducing new signs of cultural rebirth. On the other hand, it radicalizes the memory of places [Ciotta 2012]. The increasing number of artists confirms the growth of this phenomenon on a national scale, promoting events such as *Super Walls* [1] or *CHEAP* [2]. Besides, there are many events and projects worldwide, like *SHINE Mural Festival* (Florida), *Upfest* (Bristol), *Street Art Fest* (Grenoble), *Afri-cans Street Art Fest* (Kampala), *HK walls* (Hong Kong), *MURAL Festival* (Montreal) and *Brisbane Street Art Festival* (Brisbane). Different international projects aimed to connect artistic works within urban fabrics in Madrid [3], Barcelona [4], Lisbon [Guimarães et al. 2016, pp. 3654-3657], Glasgow [5], Vienna [6], USA [7]. Instead, Street Art shows a slow development in areas with strict regulations, like the movement *Streets are yours* promoted in Japan. In China the Street Art was applied on the walls of many schools in 2016 to promote the return to class in disadvantaged areas through the project *Back to school China*. Finally, the foundation of extraterritorial associations that promote street art linked to specific global issues, such as slavery and child labor, is growing (i.e., https://streetartmankind.org). The topic's relevance has led to the creation of journals devoted to street art, such as the *Street Art & Urban Creativity Scientific Journal (SAUC)*, thematic journal issues [8], or specific workshops [Casimiro 2019, pp. 1-2].

In a global communication framed by massive use of images and videos, the growth of this artistic movement may benefit from these digital channels. The link between artworks and descriptive or multimedia content can significantly improve street art understanding, valorizing the presence in the territory. Augmented Reality (AR) is a tool to read "beyond the visible", providing a multigenerational stimulus that brings different audiences closer to Street Art, proposing new cultural paths. A cultural approach compliant with the street art principles and its contents requires answering the following questions:

– Can the digitization process be respectful of a street artwork?

– What is the balance between permanent digital data and temporary art?

– Could the interest in applying AR tool overcome the attraction in the real artwork?

The authors try to answer by proposing a critical analysis of the main characteristics of street art and the pros and cons of AR in the domain.

Main Street Art Features

Urban art can be considered a wide container within multiple artistic currents converge, from graffiti to street art, with specific materials, communication, and representation [Arnaldi 2014]. Often street art describes contemporary subjects or political themes, provoking people and creating a deep relationship with public spaces and inhabitants. Some features are relevant for understanding the street art essence establishing a respectful relationship.

The "democratization" of contents and communication is the first one. Street art has become a socio-cultural phenomenon defined by dynamic connotations with no precise edges. For these reasons, the artistic subjects expand the audience to all ages and cultural backgrounds. The flourishing of many events organized by cultural associations in collaboration with public institutions worldwide exemplifies this trend, leading the art into a more framed flow. At a national scale, the Cultural Association *MURo* [9] promotes festivals and urban art projects, fostering the idea of a diffuse museum of Urban Art in Rome. In the same district, the social projects *Big City Life* (2015) and *Moltitudini – Big City Life* (2018) [10] allowed to requalify some buildings in Via di Tor Marancia and Tor Bella Monaca. Another projects are *Diciamo Insieme Grazie* and *Dominio Pubblico – MILLENNIALS A(r)T WORK – MA(r)T*; the first

left a testimony on Covid-19 emergency, the second bring up young people contact the urban fabric and contemporary art. Despite these examples, several artists want to preserve a connotation of illegal activity and free experimentation, working in degraded urban areas or abandoned buildings. At last, art democratization refers to the urban transformations and human sensory limitations that can neglect art accessibility.
The concept of temporary street art, named "impermanence" [Meschini 2020, pp. 1-22], is a second pillar. Artists are aware of the limited durability of their works, due to the materials and techniques used or to the "illegal act" connotation that makes them liable to removal. Artwork can be subjected to tears, vandalism, removals, thefts, and natural deterioration, exploiting the incisiveness of the image through its dissolution. Some techniques are devoted to speed the realization and the communicative impact. They are often ephemeral results that become a heritage imprinted in the collective memory. This latter is conceived in a participatory form to relate people and places through installations designed to be destroyed, torn, disassembled, and taken away in fragments as memories. They are subjects to people's good decisions, bad intentions and weather events, determining all their transformation during the time. The disappointment for the limited lifetime arises from external people, while the artists claim its key role in the art. Some other artists are searching for a new meaning of permanence in terms of techniques experimentation, assigning a function of environmental sustainability. Finally, there are some examples of restoration of artworks, removing graffiti and tags that limit the art reading.

Digital Street Art

The physical and digital worlds, framed in the street art domain, highlight a complex relationship with apparently antithetical characteristics. The digitization of artworks improves their visibility in the territory, facilitating their search, accessibility, and classification [Novak 2015, pp. 13-25] and digitally freezing their state of art [Rodriguez-Navarro et al. 2020, pp. 1-22]. Nowadays few national and international databases collect the artist's works and relative characteristics. An example is the *Street Art Cities platform* [11], which catalogs and collects many street artworks worldwide, linked to a geographical map. In Rome, there are similar projects, such as the *GRAArt project* [12], conceived by David Diavù Vecchiato and MURo association. It traces the history and myth of Rome on the walls of the *Grande Raccordo Anulare*, mending the cultural gap between the monumental historical center and the suburbs [AA.VV. 2020]. A second project is *STREETART ROMA* (Artribune) which allows finding the artworks in the Capital area within mobile systems. The project has a broad audience offering geo-data integrated with the text, images, and videos. Finally, there are some examples devoted to single artists. *Banksy Street Art Treasure Map* is a free app for IOS mobile systems dedicated to Banksy's works worldwide. *Millo's official website* presents a map for exploring and viewing his works. In this framework, artworks digitalization and geo-localization simplify the construction of virtual itineraries, strengthening different cultural and thematic connections. It also allows freezing operas, fixing their conservation condition in a digital trace. However these pros, the digital replica lacks the physical relationships with its territory.

Fig. 1. Sequence of works that present the need for supplementary information that deepens the citation, the generative or constructive principle. a) The Deposition of Truth (Sirante); b) Piekary (Sten&Lex); c) Punto di fuga (JR).

The digitization can provide additional contents (2D/3D iconic-graphic info, static or animated data) simplifying the understanding of the representative mechanisms behind the artwork without interfering with a direct reading. Firstly, it can help reading the connection between different operas by descriptive information and links to the artworks, such as Sirante's *The Deposition of Truth*, based on *The Deposition from the Cross* by the painter Rogier van der Weyden. A second application may explain particular techniques to achieve specific results, like Sten&Lex operas. According to black and white lines, they work with the stencil poster technique based on very fragile paper matrices. The artwork generates different perceptions according to the viewing distance, recalling the world of Optical Art. So, the artwork can be better explained deepening the optics principles. Finally, it can be crucial to use digital data to explain the works' geometric construction by referring to perspective principles. An example is JR's perspective anamorphosis of *Punto di fuga* artwork, a large-scale poster art (Fig. 1).
A solution that may preserve the characteristics of the works and provides integrative digital content is represented by Augmented Reality. It is a tool in which real and digital converge, allowing to explore and perceive information not contained or not immediately/visually perceivable in reality [Geroimenko 2014]. However, the interest in applying this tool may overcome the attraction in the real artwork. For this reason, it is appropriate to plan a critical design process that identifies the most suitable content, improving the art perception without replacing its direct reading and the relationship with the environment.

AR for Street Art

The augmented reality process is defined by steps which can be declined to multiple application areas [Russo 2021]. Content democratization, art impermanence, and image recognition are crucial in AR planning for street art applications. Urban art belongs to everyone, so democratization refers to the user's domain, consistent with the purpose of the work. The AR users must range from children to the elderly. Accessibility is, therefore, a critical prerequisite, which is reflected in the type of device, the AR applications, the virtual interaction, and the content complexity. Smartphones and open-access applications are considered a suitable solution. The level of interaction must be engaging but straightforward, enlarging to a broad audience. Finally, it is appropriate to avoid both trivial and complex contents, by promoting accessibility and meeting interests for multi-generational people.
The content linked to the work is critical since it defines the relationship with the work and the cultural growth of the user. First, it must be consistent with the type of work, offering insights of a geometric-constructive nature, transversal reading, descriptive contents, or inspiration suggestions. Besides, the content visualization should neither replace nor hide the work, highlighting the opera, its relation with the context, feeding a new experience and interaction. The content may range from texts to photos, from drawings to interpretative 2D/3D models and videos. Data simplification and description must consider the audience, the work of art, the user experience, and the level of interaction (Fig. 2). Besides the content, a second AR pillar concerns art recognition techniques. The geolocalization (markerless mode) makes it easy to build itineraries, simplifying the recognition of artworks that present low accessibility. On the contrary, it can lead to a possible mismatch in the artwork recognition and it is invariant to the urban and artwork transformations, so it is not suitable to preserve the link between art, its trasformation and the environment. Marker recognition, expressed through coded images or 2D/3D geometries, creates a direct relationship with the subject, offering a more consistent solution with art impermanence, the context of insertion, and fruition (Fig. 2). This approach can show some limitations in itineraries construction and artwork fruition if they are located in confined places. Several AR projects for street art communication and promotion have been proposed in recent years. *MAUA* [13] is an open-air museum project spread over several cities, allowing the transformation of the works in a participatory way. This project has ignited the interest in AR street art, even if it suggests an overlap of graphic reinterpretations that only par-

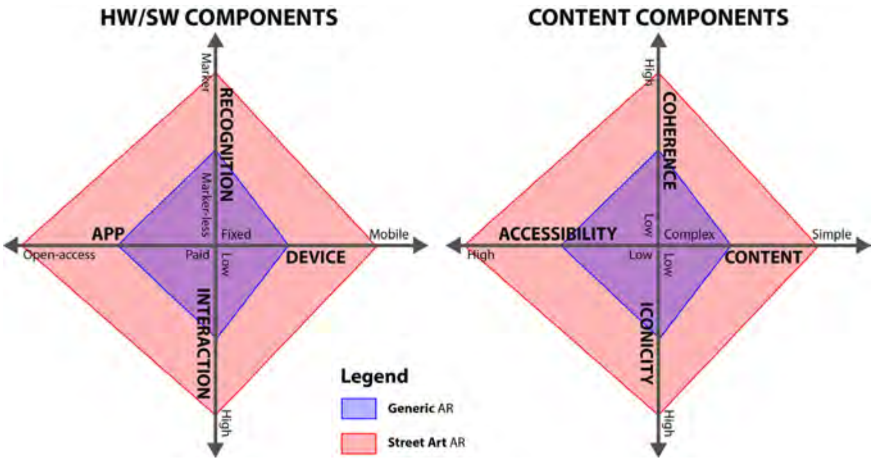

Fig. 2. Star diagram with main hardware/software and content components related to AR for street art.

tially preserve the reading of the original work. Besides, the desire to connect multimedia content to artworks with AR, improving storytelling and expanding their fruition, is a theme felt by several artists. An example is the free app *JR:murals*, which allows interacting with some artworks and accessing audio-video content.

Temporary AR Test

Based on the observations made so far, the authors analyze the image recognition topic and suggest the association of suitable content to the artwork. All AR experiments have been carried out in Unity and Vuforia platforms. We started from the logical assertion: the recognition capacity of the camera should lower with the decreases in the artwork readability. So, the art impermanence would be respected, linking the digital content to the artwork readability. Two open aspects converge on this point, justifying an experimental path.
The first regards the gradual physical decay of artworks, if not caused by anthropic interventions, compared with a sudden stop of the digital system. The second aspect refers to identifying when the digital system can no longer recognize the artwork. Although not verifying all the variables involved in the process (camera characteristics, environmental conditions, graphic characteristics of the work, viewing distance), a first experiment was planned to test this relation.The target image used is an orthophoto of the artwork *Jeeg Robot* by Solo, created within the project Big City Life – Moltitudini 2018. Starting from this image, the time

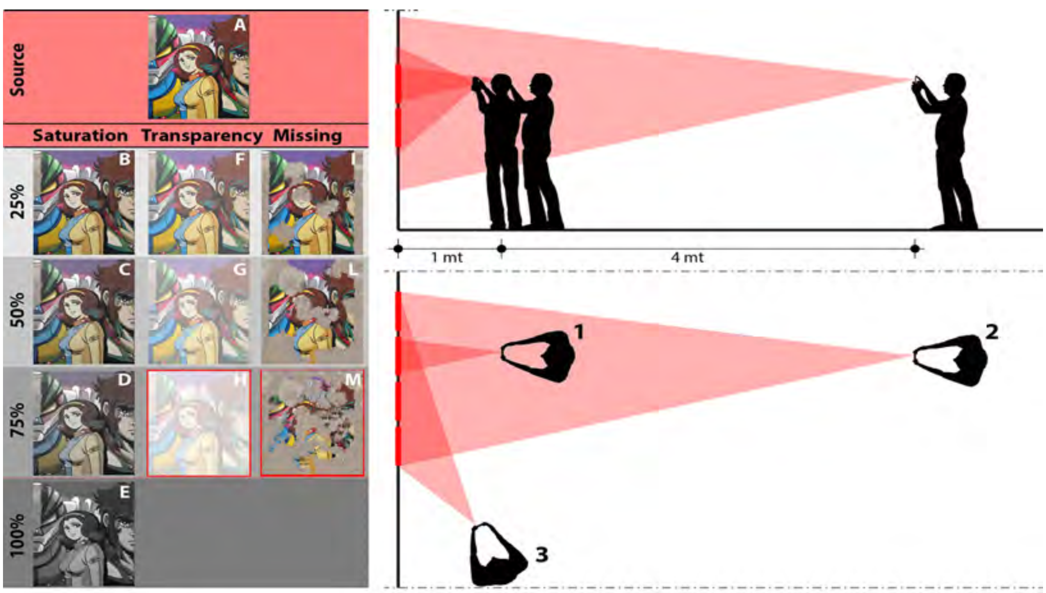

Fig. 3. Scheme of the experimentation: on the left are the different types of targets that simulate the transformation of the artwork in time; on the right, the scheme of taking in plan and elevation.

effect has been digitally simulated. The variation of color saturation is intended to simulate the color lack. The change of transparency corresponded to the uniform leaching effect. The progressive loss of reading areas simulated the wall damages, the presence of overlapping elements or artwork lacks. The different prints have been positioned on the same wall, unifying the lighting conditions and avoiding the effect of backlighting given by display projection. The smartphone's camera (A3 Samsung) was positioned at a distance of 1 meter from the target images, with the optical axis perpendicular to the wall (Fig. 3). In this passage, the image recognition failed for two prints: the one with 75% transparency and the one with 80% of area reduction. The number of features still present in the remaining part affected the latter result, stressing the ratio between features and preserved area. Conversely, the color desaturation did not make any difference in image recognition. A second test was led 5 meters far from the wall, still with a perpendicular axis. Such distance allowed framing the different classes of variables simultaneously. The experiment showed a reading priority of the images that contain more features. The color does not intervene in this priority, considering the image with a different saturation value at the same level. In the third and last test, the camera was positioned oblique to the wall. This experiment identified the priority between similar images in the distance criteria, choosing the closer image.

AR and Street Art in Rome

Based on the experiences, an AR application has been tested on three different case studies in Rome with the figures of Anna Magnani (Fig. 4). The first example is a large-scale mural on a flat surface, created using the paint mural technique by Lucamaleonte. The work depicts three different faces of the actress with two yellow-red roses, recalling the city of Rome, the Roma team, and the film La rosa tatuata (1956), directed by Daniel Mann. For these reasons, it was deemed appropriate to link a film clip to strengthen the cinema connection. The second case study is a stencil painting by Diavù made on a series of parallel surfaces belonging to a staircase. The work is titled *Anna Magnani – La Diva*, which does not reference a specific film. For this reason, the example lends itself to the connection with an explanatory content of the representative model, underlying the realization of the work by anamorphosis of decomposition. In this case, two additional elements do not favor artwork recognition. The anamorphosis requires seeing the artwork from a specific point of view and extracting the correct representation. It works both for the target acquisition and for the AR application. Besides, the multiple planes of the representation do not fit well with the camera's focal plane and the normal of the planes to fix the digital content. So, the recognition process depends on the point of view, the number of projection surfaces and the features contained in each plane (Fig. 5). The third and final case is a small flat surface affiches using the stencil poster technique. The work is by Lediesis, part of a series of stencil posters whose meaning is more linked to the women and their capacities. Therefore, Anna Magnani's image represents the universe of strong women. So, it was considered more consistent to link the work to an interview with the Lediesis, explaining the general meaning in the use of female figures.
The experimentation revealed several bottlenecks in the application process. In the case study of Lucamaleonte, a determining factor was sunlight, which illuminates the entire surface at certain times of the day. This boundary condition has obliged to balance the AR videos transparency better, preserving the work's legibility and AR content (Fig. 6). Diavù's staircase showed the importance of identifying decomposition's correct vanishing point of the anamorphosis. It determines the correct legibility of the AR. The presence of numerous planes makes identifying the image by the camera complicated, simplified by using the central part of the image as a target (Fig. 6). At the same time, the presence of steps in the video transparent background confuses the visualization of the content, preferring a non-transparent visualization. Lediesis's artwork presented an obstacle that prevents the work from being read in its entirety. The contents have been presented without transparency (Fig. 6), while the transition from nadiral to tangential makes the AR unstable.

Fig. 4. Case studies analysed in the experimentation: a) Anna Magnani in Tiburtino III (Lucamaleonte), Anna Magnani. La Diva e la donna in Nuovo Mercato Andrea Doria (Diavù), Anna Magnani in Trastevere (Lediesis).

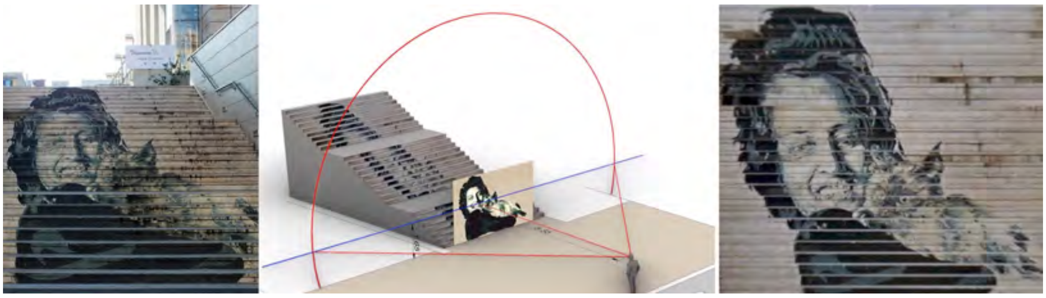

Fig. 5. Photographed staircase (left), geometric-perspective scheme with vanishing point and projection of the plane onto the steps (centre), anamorphosis reprojected in true form (right).

Fig. 6. Experiments with AR in the three case studies with video in transparency (left), animation (centre) and top video (right) within Unity and Vuforia environment.

Conclusions

The proposed research focuses on AR to enhance and understand Street Art, suggesting a respectful digital-real relationship with the artist. In particular, it is critical to keep the democratic content and the possibility of non-durability of the work, suggesting a consistent interaction in a multi-platform open-source application. Besides, the image recognition approach establishes a direct relationship with the physical artwork, setting the digital function according to the art conservation. This passage preserves the direct link between the work and the digital content, with regard to the durability of the work. The art recognition highlights some bottlenecks, given by the applied techniques, the external light conditions and the shape of which the artwork is represented. For example, in the anamorphosis recognition requires solving both the reverse perspective, looking for the preferred point of view and the mismatch in the recognition by the camera. This problem may change when dealing with works projected onto different (e.g. cylindrical) and complex surfaces. Finally, the AR content must enhances the work without hiding it, choosing the most suitable textual, multimedia, or 3D data. The content's accessibility is connected to the democratization aspect, ranging over the levels of iconicity and the target audience. AR in urban art can substantially contribute to fueling the growth of this domain if designed according to a priority of content consistent with street art. The experiment in the paper suggests a possible critical approach to the problem. Besides, the topic traces a research domain defined by a multidisciplinary connotation, opening new research scenarios.

Attributions

The authors all contributed to the development of the research. In the writing of the article, the authorial attribution is as follows: F.C. was responsible for the paragraph "Temporary AR test," E. I. wrote the introduction, A.M. was responsible for writing the paragraphs "Main street art features" and "Digital street art," and finally M.R. wrote the paragraph "AR for Street Art" and the conclusion.

Notes

[1] https://www.biennalestreetart.com/

[2] https://www.cheapfestival.it/

[3] http://madridstreetartproject.com/

[4] https://www.streetartbcn.com/

[5] https://www.citycentremuraltrail.co.uk/

[6] https://www.startnext.com/viennamurals

[7] https://streetartunitedstates.com/

[8] http://disegnarecon.univaq.it/ojs/index.php/disegnarecon/issue/view/27

[9] http://muromuseum.blogspot.com/

[10] http://www.bigcitylife.it/

[11] https://streetartcities.com

[12] http://www.graart.it/

[13] https://mauamuseum.com/

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The via Annia in Padua: Digital Narratives for a Roman Consular Road

Giuseppe D'Acunto
Maddalena Bassani

Abstract

A new collaboration between Iuav University of Venice and the Musei Civici of Padua was introduced in 2021 as part of the activities of research and teaching of Iuav University. Its aim is the study and the enhancement of finds preserved at the Archaelogical Museum of Padua. This collaboration has also given the opportunity to carry out a series of research on matters related to Padua as a roman city and its urban developments, and on some artefacts preserved in the city Museum. The supervisors of this collaboration are Maddalena Bassani and Giuseppe D'Acunto, professors at Iuav University of Venice, and Francesca Veronese, director of the archaeological section of the Musei Civici of Padua.
In the following paragraphs, we present the first outcomes of this collaboration, which has been particularly promising on several levels. First of all, it has been a fruitful opportunity for Iuav scholars involved in this project to approach pragmatically the urban and architectural becoming of one of the most important cities of the Roman period of the Veneto region. Secondly, it has enabled to go to the Museum, appreciate the exhibitions, and to face the problems linked to the graphic restitution of finds and ancient environments. This project has also lain the foundations for further collaborations between Iuav University and the Musei Civici with the aim to encourage the knowledge of an already known – but only partly visible – past, and to make the general public appreciate it.

Keywords
archaeology, digital reconstructions, immersive reality.

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The Object of the Research: the Via Annia in the North-Eastern Area of Patavium

The analysis of the particularly stimulating north-eastern area of Padua in its Roman times [1] has been the subject chosen among the various possible topics of study and research offered by the rich and articulated Paduan Museum. This part of the city is characterized by significant monumental and infrastructural complexes because it was crossed by the roman via Annia, which took its name from Tito Annio Lusco, consul in 153 BC [2] , who promoted its construction.
The via Annia and its path between Adria and Aquileia have been the object of a long-time interdisciplinary project [3]. This project has allowed not only the publication of various contributions useful for reconsidering known aspects and proposing original [4] ones but has also allowed to analyse in depth and display the remains of the road and the monuments overlooking it in the cities crossed by the road itself and which have an archaeological museum.
An *ad hoc* exhibition about the via Annia in the territory of Padua has been set up inside the Musei Civici of Padua with panels and, in particular, finds that help the understanding of buildings, infrastructures, and funerary monuments that could be seen by those who entered or exited the city via the consular road.
The choice of the north-eastern area of the city was determined by two main factors. Firstly, in this part of the city there are multiple ancient evidence that could therefore be easily accessed by the students in valid and recent publications. Secondly, funerary monuments are exhibited in the Museum and can be studied *in situ* by the students by permission of Francesca Veronese and the staff.
The focus of the first phase of the research was the analysis of the section of the Roman consular road delimitated by Porta Altinate and the area of the eastern necropolis along the old road (Fig. 1) [5]. The first steps required a preliminary and essential study of the history of the city and its main evolutionary phases from the urbanistic, monumental, and historic-cultural points of view.

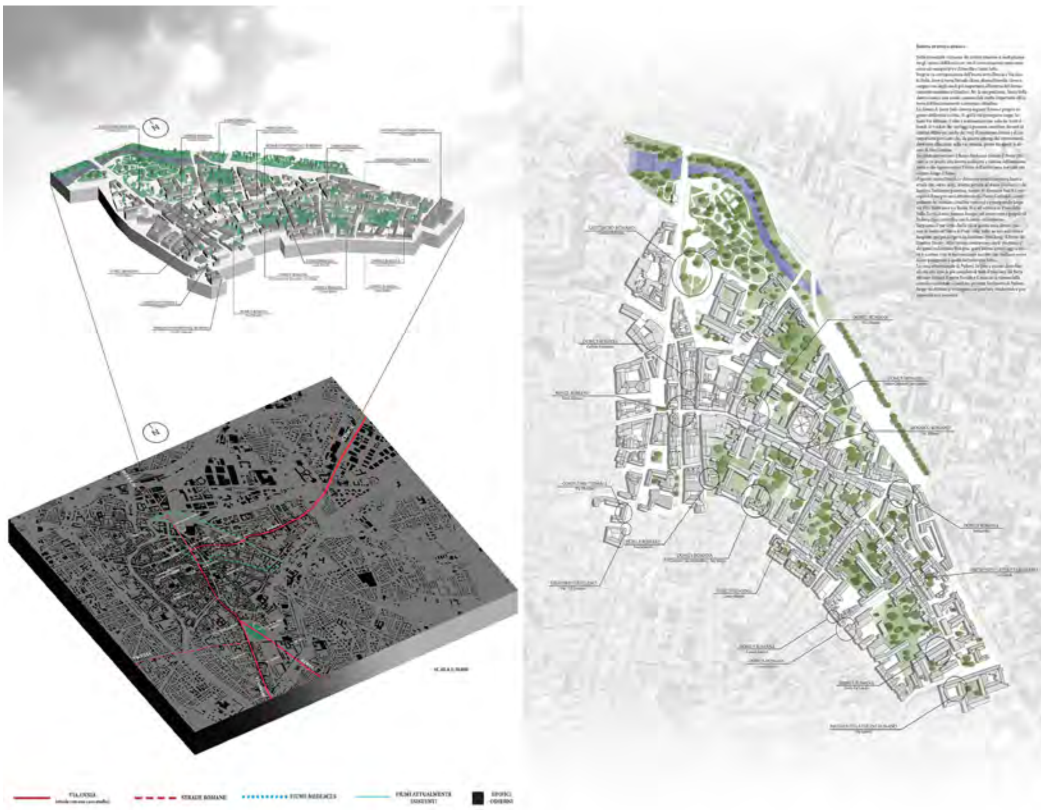

Fig. 1. Reconstruction of the northeastern sector of Roman Padua along the Via Annia. Digital processing by Andrea Maso and Paolo Chiocchetti.

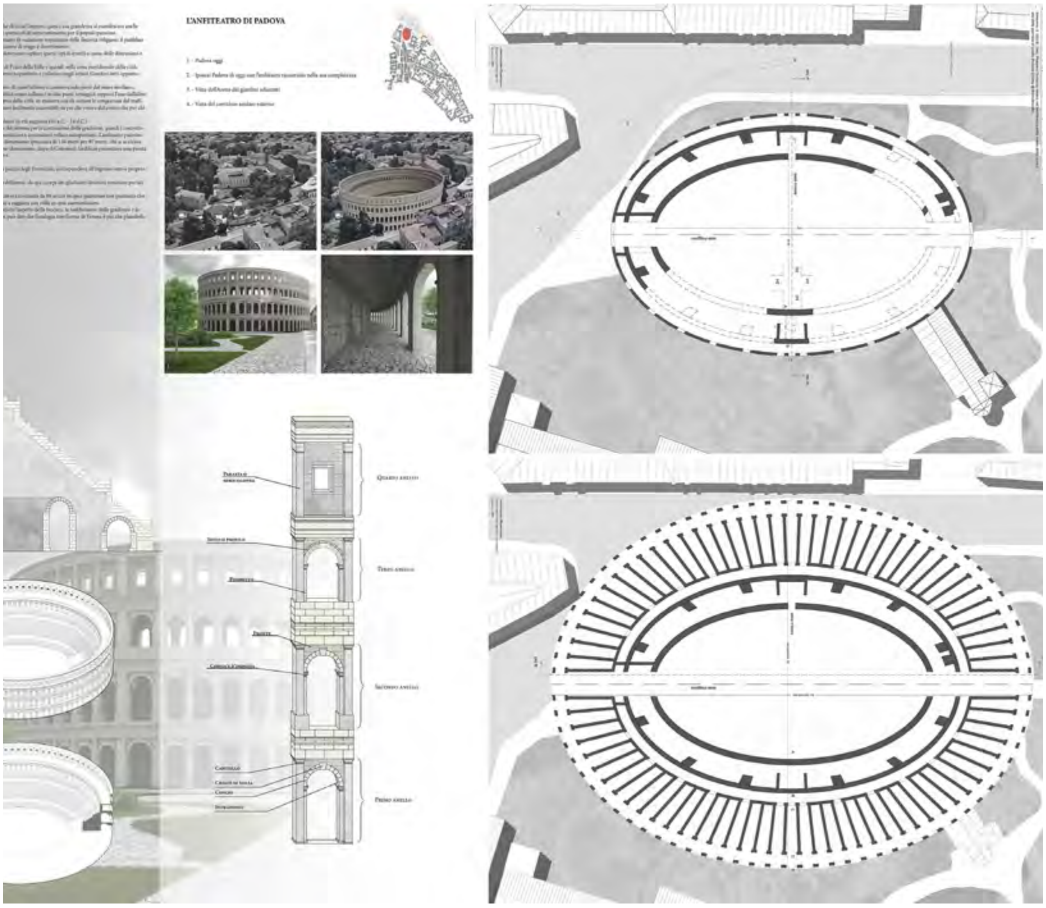

Fig. 2. Reconstruction of the Roman amphitheatre of Padua. Digital processing by Andrea Maso and Paolo Chiocchetti.

The focus of the second phase of the research was instead the acquisition of the available bibliographic documentation relating not only to the road in its urban and suburban development, but also to its whole layout in the Decima Regio Augustea. The aim was to understand its peculiarities and recurrences inside the five main Roman centres (Adria, Padua, Altino, Concordia Sagittaria and Aquileia).
Thus, several buildings and infrastructures in the areas of Garibaldi Square and the hospital of Padua were selected and studied in detail. They correspond to five different monumental typologies related to the Roman road. The first one is the Roman Amphitheatre, which is among the main monumental public buildings of Patavium and can be dated to the first decades of the I century AD (Fig. 2) [6]. The second one is the Altinate Bridge which, together with san Lorenzo Bridge, is one of the flagships of the ancient Patavium with relation to civil construction (Fig. 3) [7] . In this area and beyond, towards the ancient city of Altino (from which the bridge and the gate take their name), the research focused on private buildings such as the *domus* – unfortunately only relatively known but with interesting mosaics as floor decorations (Figs. 4-5) [8] – and, above all, on the remains of graves situated outside the urban centre. It is well known that in Antiquity the funerary *monumentum* (from the Latin verb *moneo*, 'to exhort, to remind') was the means through which one's memory could be transmitted to the posterity. It is not by chance that the remains of some of the graves that were lined up along the via Annia in Roman times are multiple and significant. Two of these manufacts, both exhibited in the Musei Civici, have been digitally re-elaborated: a I century AD [9] festooned ara commissioned by Attia Secunda for her husband Manius Cutius Philargurus (Fig. 6), and the famous I century BC stele of Ostiala Gallenia. The latter is one of the most significant finds of the Musei Civici, because it is a tangible proof of the crucial moment of cultural and political transition of Padua from city of the Venetians to Patavium as Roman city [10].

The Digital Actualization of the Research: from the Acquisition of Data to Representation

The research on the via Annia and the collaboration with the Musei Civici of Padua have been a new and interesting chance for Iuav University of Venice to reflect once again on the theme of "digital humanities". "Digital humanities" is the digital transposition of reality, also meant as memory of the past, in which it is possible to create new relations and new connections between contents usually distant from one another and based on interpretative methodologies that lead to a reconsideration of the whole cultural heritage.
One of the fields in which this debate is more fruitful is indeed the archaeological one, where new protocols and paradigms are widely applied to digital reconstructions of archaeological models with a strong semantic character and critic interpretative style. In that sense, the rigor of the reading and the interpretation of archaeological data can be expressed in digital reconstructions based on a professional and thorough philological approach and therefore on the critic and informed analysis of trustworthy historic and various sources – all elements that originate an interesting debate and an interdisciplinary dialogue. The digital models created with the above-mentioned approach become a synthesis of different and heterogeneous information, capable of evolve towards a rich and rigorous graphic apparatus long-awaited in the archaeological field. In this specific case, this apparatus becomes the cornerstone of a narration that uses sophisticated digital and interactive systems to express its ability to dialogue with the general public.
As an example, we can sum up the main phases of the digital reconstruction of the amphitheatre. This work fully expresses, maybe better than anything else, the multidisciplinary approach of the whole project and its ambition to offer a complete and unitary representation of the manufact in its original state by transforming the few remains still visible nowadays, obtained with a metric and digital survey, into a digital model that enables to complete the missing parts. In this process of completion, meant as reconstruction in the widest sense possible, the dialogue between archaeologists and designers is essential. The model, in the process of its virtual creation, becomes the object of check and verification by the scholars of the different hypotheses proposed by the critics, who do not always agree on the formal and dimensional aspects of the original manufact.
The critics agree that the Paduan amphitheatre was built in Augustan times. It seems certain that the Paduan arena was meant to be the third biggest one of the whole empire and it was built demolishing a pre-existing water main in the northern part of the city – the current Giardini, which are in fact called Giardini dell'Arena (Gardens of the Arena).
Nowadays only part of the middle wall is visible. This enables to presume the whole planimetric layout and its relative dimensions – an elliptic plan with its major and minor axes measuring respectively 134 and 97 metres [11].
Scholars agree also on the hypothesis that the ordinary plan of the Paduan amphitheatre was similar to the one of the Verona Arena from both the dimensional and the constituent points of view. This theory was particularly relevant during the whole process of digital reconstruction, because the plan was completed with its missing parts thanks to symmetries with the surveyed ruins and the identification of the different concentric and coaxial ellipses that define the perimeters. Then, the totally missing parts were integrated by means of formal and distributive analogies with the plan of the Verona Arena.
No element able to envision the original appearance of the façade, the subdivision of the stairs, and the position of the respective *vomitoria* has survived. In this case too, the analogies with the Verona Arena and the estimated data of the plan suggest a vertical building spaced by 80 arcades in *opus quadratum* with stairs supported by a system of cylindric vaults in *opus caementicium* and by spaces arranged in a radial pattern.
Therefore, similarly to what has been done with all the other buildings that are the object of the present research, the digital reconstruction of the amphitheatre was based on the data of the survey of the ruins obtained from laser scanning and photo modelling, and from formal and dimensional analogies with contemporary buildings that were

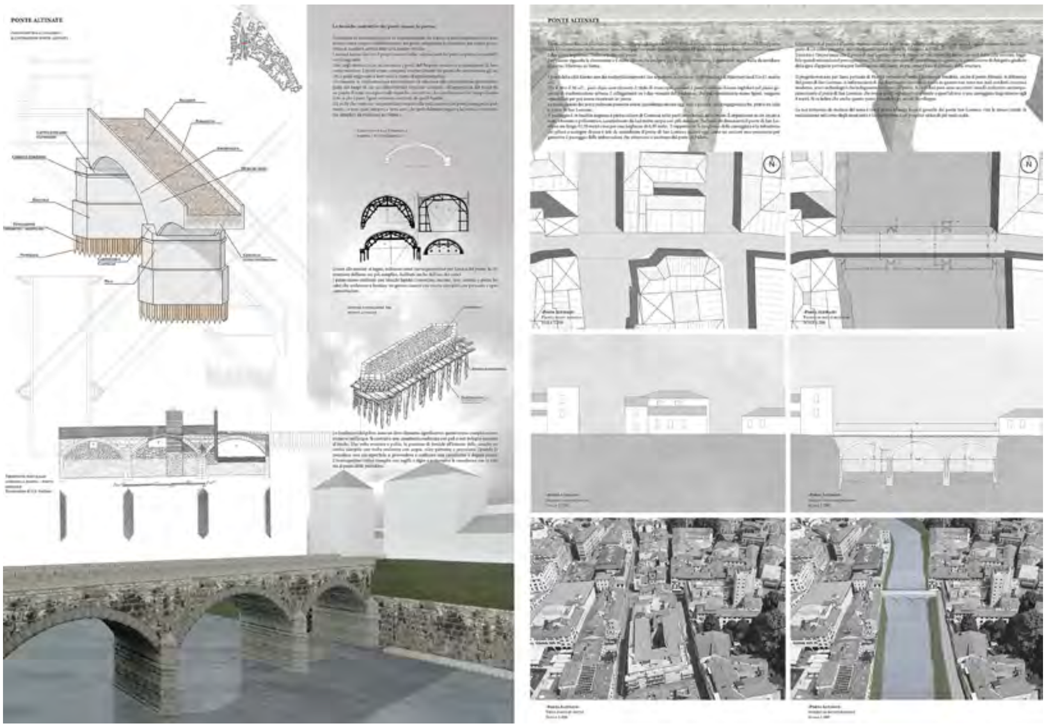

Fig. 3. Reconstruction of the Altinate Bridge in Padua. Digital processing by Andrea Maso and Paolo Chiocchetti.

situated in neighbouring places, were of the same typology, and had the same function. In the second phase of the research, which is currently in progress, these digital reconstructions are inserted in a sophisticated explanatory and narrative system that works with the perceptive and sensory mechanisms and exploits the illusory effects generated by the use of various devices. Thus, it allows to turn a chosen space inside the Paduan Musei Civici into an immersive environment able to virtually "immerse" the public in an experience that can enrich and integrate the narrative themes in the real exhibition space each time. In this case, the choice to use immersiveness derives from a thoughtful critic reflection and from a strategy that is coherent with the rest of the exhibition process, where the integration of traditional solutions and "storytelling" merge into a highly effective narration thanks to the ability of those two systems to dialogue and complete each other.

Final Notes

The first steps of this new collaboration between Iuav University of Venice and the Musei Civici of Padua have therefore enabled not only the realisation of a first phase of the research, but also, and most of all, the prefiguration of further in-depth studies that will be carried out in two different ways. On one hand, new research dealing with the study and the digital reconstruction of other areas of the city and its suburb could be carried out, enabling scholars and students of Iuav University to approach the knowledge of the historic and archaeological heritage of Padua and to become aware of their perception in view of their professional career. On the other hand, the enhancement of finds exhibited in the Museum could be the means to reconstruct their origin, their complete morphology (if the find is a fragment), and their "history" through time in a broad sense. Thus, it will be possible to give visitors a wider and more articulate narration, both in terms of content and of exhibiting system, of an inscription, a mosaic, or a tomb panel – which could otherwise all be perceived as mute and not attractive manufacts, apart from the "aesthetic" or functional points of view.
Ultimately, this collaboration constitutes another piece of the currently wide panorama

regarding digital reconstructions of great contexts and individual archaeological manufacts realised for museums, archaeological sites, or precise excavation sites. Above all, an approach towards the study of antiquities that involves different disciplinary fields can be developed through this type of research, putting young people in contact with the knowledge of the past in order to plan the(ir) future.
Archaeology and architecture can therefore only be joint partners in the construction of the future.

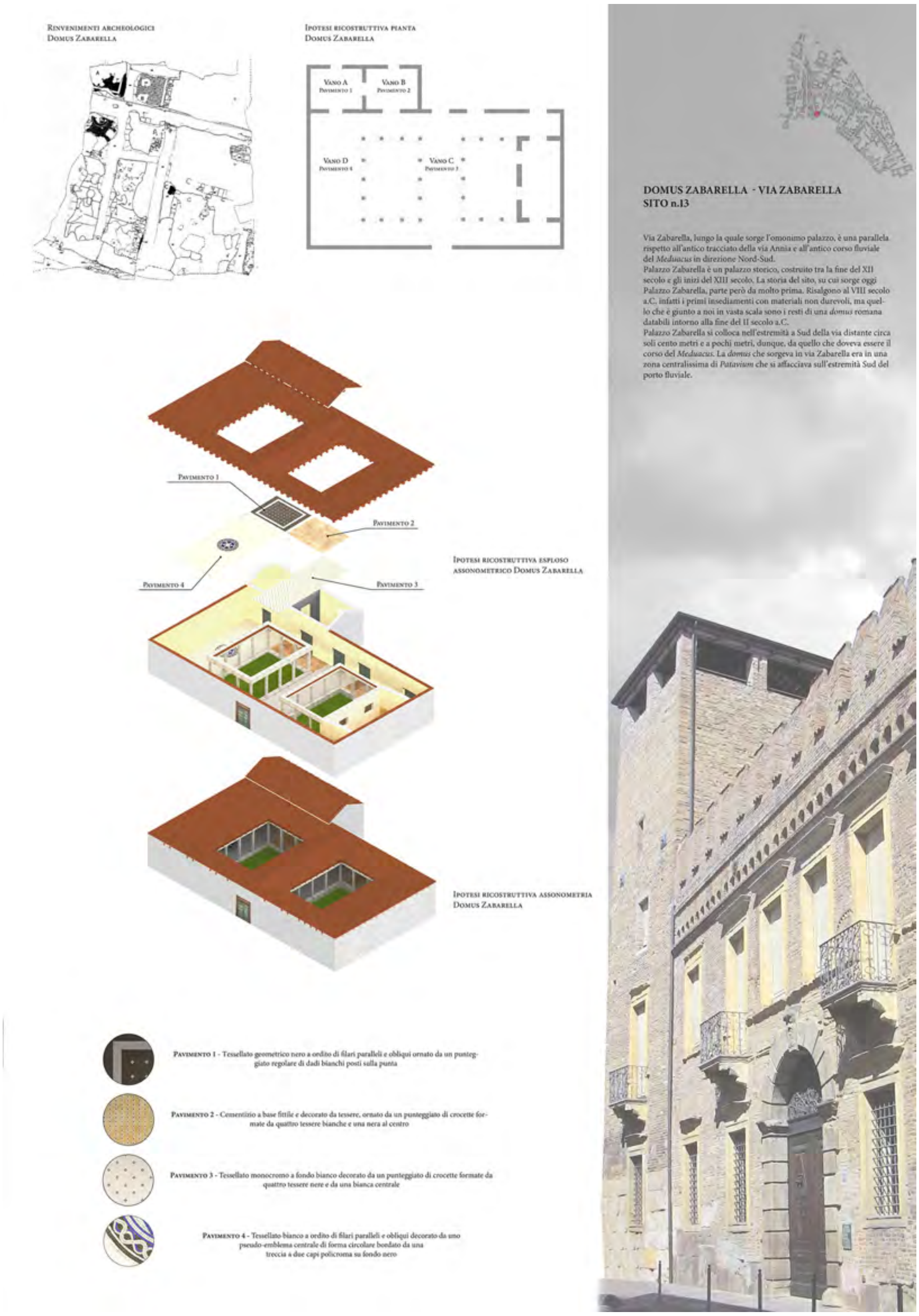

Fig. 4. Reconstruction of the Domus Zabarella in Padua. Digital processing by Andrea Maso and Paolo Chiocchetti.

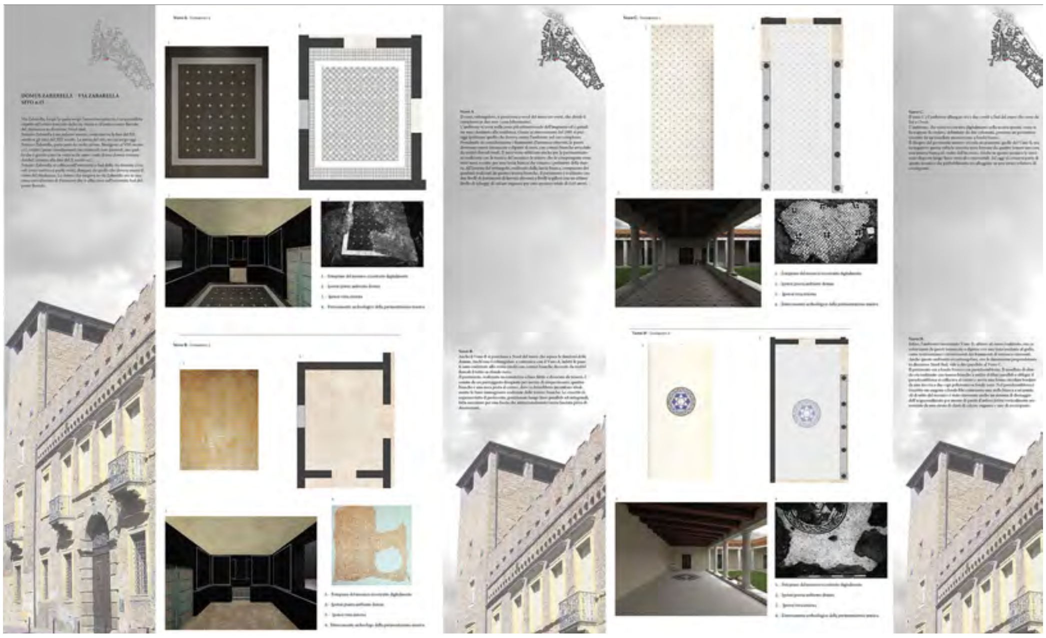

Fig. 5. Reconstruction of the Domus Zabarella in Padua. Digital processing by Andrea Maso and Paolo Chiocchetti.

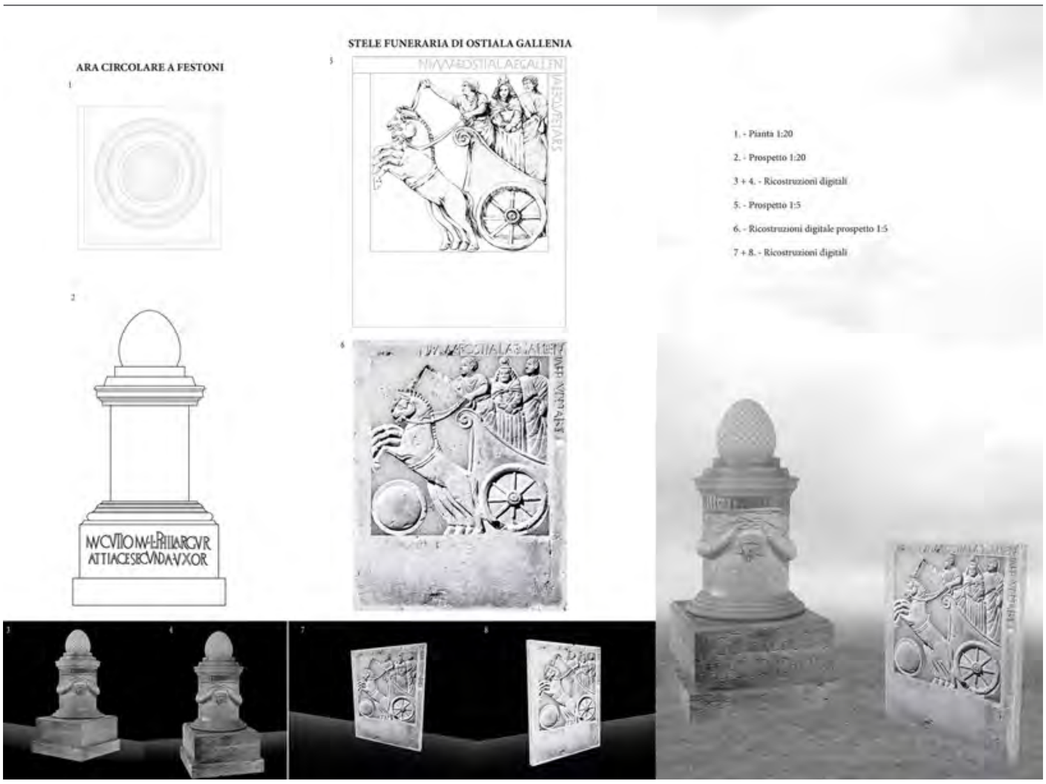

Fig. 6. Reconstruction of the circular festooned altar and the funerary stele of Ostialia Gallenia. Digital processing by Andrea Maso and Paolo Chiocchetti.

Notes

[1] On the history of the city see the concise but recent compendium in Bonetto, Pettenò, Veronese 2017 and Veronese 2018.

[2] On the reconstruction of the entire route of the Roman consular road, see Uggeri 2012 and 2017.

[3] The project was coordinated by Francesca Veronese from 2007 to 2010.

[4] Veronese 2009; Rosada, Frassine and Ghiotto 2010; on the reconstruction of the traces of the Roman road between Altino and Padova, particularly about the urban section, see the contribution of Bassani 2010.

[5] The research mentioned here and the images in this contribution are taken from the dissertation presented at Iuav University of Venice for the academic year 2020-2021 titled L'Annia e la Padova Romana by graduands Andrea Maso and Paolo Chiocchetti in a work dedicated to Iuav University of Venice for the Master's Degree in Architecture and Innovation, with Giuseppe D'Acunto and Maddalena Bassani as supervisors.

[6] Bressan, Veronese 2017.

[7] Galliazzo 1995; Braccesi, Veronese 2014.

[8] Rinaldi 2007.

[9] Pettenò 2009.

[10] Di Filippo Balestrazzi 2012.

[11] Braccesi, Veronese 2014.

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Perspective Between Representation and AR: the Apse of the Church of St. Ignatius

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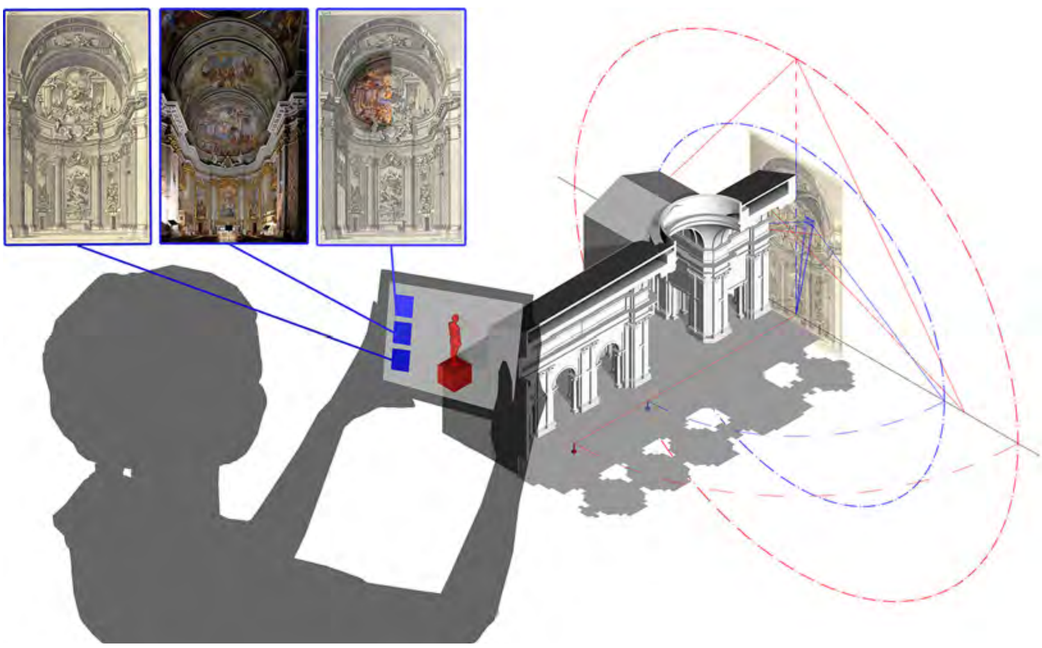
Abstract

This contribution studies the ways in which Augmented Reality (AR) can communicate and disseminate knowledge about our cultural heritage in general and, in particular, Architectural Perspectives (AP). The focus is to increase our knowledge and understanding of perspective technique and how the latter deals with the unique mix between the real architectural environment and an illusory space, in this case the decorations of the presbytery and apse of the Church of St. Ignatius in Rome. The specific objective of the study is the possibility to use the Pozzo's treatise to "augment" its fruition, accompanied by a virtual visit in order to gather more in-depth information about the perspective construction that creates the effect of spatial expansion thanks to this expedient. This decoration is in fact one of the rare cases of a perspective representation of a pictorial project, in turn also a perspective designed by Pozzo; this design is the "activation" element of an AR experience that immediately illustrates the perspective bravura of its creator.

Keywords
perspective, treatise, augmented reality (AR), architectural perspectives (PA), Andrea Pozzo.



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Introduction

This contribution will reflect on the ways in which Augmented Reality (AR) can communicate and disseminate knowledge about our cultural heritage in general and, in particular, Architectural Perspectives (AP). Following in the footsteps of our proposals illustrated during the REAACH-ID meeting 2020 [Carlevaris, Fasolo, Camagni 2021], the current objective is the dissemination of knowledge regarding perspective technique and how, when large-scale artifacts are involved, it deals with the unique mix between the real architectural environment and the illusory space [Sdegno 2018].
The idea behind our proposal is to shift the activation target of the augmented experience from the architectural reality containing the AP to the images and, in particular, to the pages of many treatises where these perspectives are illustrated, explained, and constructed. Treatises on perspective are therefore the protagonists of this study phase; we intend to assign them a key role in the theory and practice of the construction of illusory architecture and also broaden their fruition so as to involve scholars and users interested in the close relationship between real architecture and illusory *trompe l'oeil* – elements firmly linked to the key idea of "design".
The text and iconography taken into consideration and examined as a case study is Andrea Pozzo's treatise published in two parts in 1693 and 1700 [Pozzo 1693; 1700], while the PA that provides the opportunity for the experiment is his design of the presbytery and apse of the Church of St. Ignatius in Rome [Bosël, Salviucci Insolera 2010]. This decoration is one of the rare cases of a perspective representation of a pictorial project, in turn also a perspective [Pozzo 1700, Fig. 81] (Fig. 1). The image very successfully communicates the perceptive result expected by the designer regarding the *trompe l'oeil* and reveals the skillful pictorial recreation and exchange between the (real) vaulted surfaces and the painted architectures.
Pozzo provides a detailed dimensioned plan and elevation of the apse and presbytery [Pozzo 1700, Fig. 82] (Fig. 2), intentionally inserted for all "scholars who also wish to revel

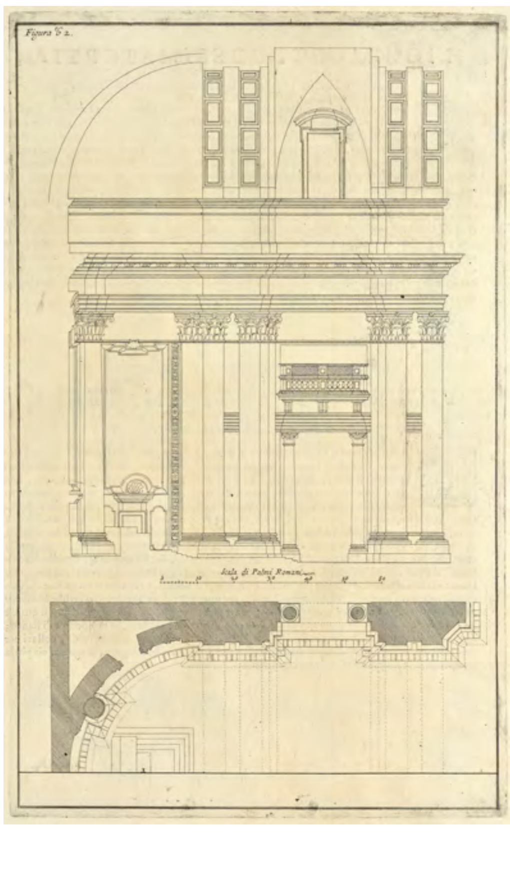


Fig. 1 Pozzo 1700, Part Two, figure 81 [Pozzo 1700].

Fig. 2 Pozzo 1700, Part Two, figure 82 [Pozzo 1700].

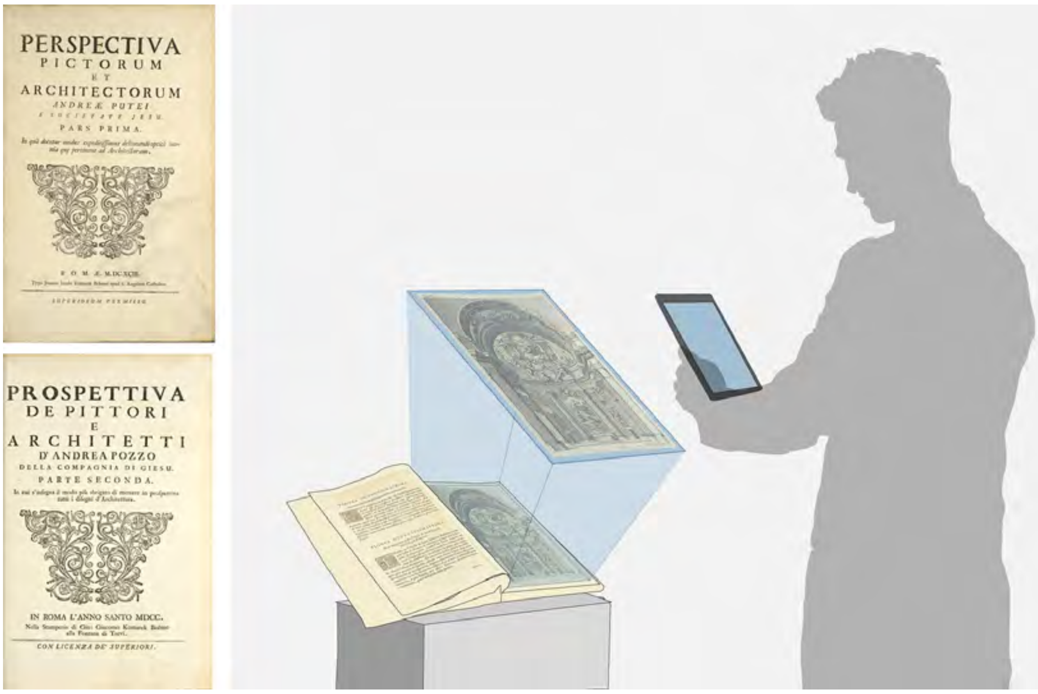


Fig. 3 Right: concept image of the AR application augmenting the treatise. Left: the frontispieces of the two parts of Pozzo's treatise: Part One, 1693, in the Latin version (top) and Part Two, 1700, in the Italian version (bottom).

in putting them into perspective" [Pozzo 1700, text relating to Fig. 82]. Apart from this declaredly didactic intent, the Jesuit father introduces many aspects of Pozzo's versatile genius and creativity into his own theoretical work. This impressive treatise is certainty not just a practical text about graphic geometry: at this point the objective of the study is to reassign the treatise its role as a connector. The two volumes can undoubtedly be interpreted as a wide-ranging repertoire of architectures – real, illusory or ephemeral – as well as a model that can be used to codify representation. The formal and ornamental characteristics of the design are welded to the forms of its representation (*ichnografia, orthographia*, and *scaenographia*, as Vitruvius would say).

Representation as the Activation Target of the AR Experience

The perspective etching that "looks" towards the apse shown in figure 1 is the inspiration behind this study and becomes the activation target of an AR application we can call "multilevel".
From a methodological point of view, several steps lead the user from just observing the treatise to virtually repositioning the page with the perspective table inside the real architectural space it represents. This is achieved by creating a three-dimensional model of the architectural work. The perspective mechanism, closely associated with the observer of the etching, is staged inside this reconstructed space. The perspective table can be virtually scaled and positioned in correspondence with the picture plane; likewise the observer/centre of projection can be repositioned inside the space of the model.
Orienting the perspective makes it possible to critically reconstruct the illusory architecture which, when suitably modelled, will be added to the real architectural space beyond the frescoed surface.
Going back to the plane dimension of the ensuing perspective will allow the AR user to not only reinterpret the projective superimposition between the architectural features in the table in the treatise and the architecture it portrays, but also establish a perceptive comparison between the frescoed surface and the same surface perspectively represented on the plane. All this is mediated by a perspective that is once again theoretical (projective) and practical.

Seen thus, the aim of the AR application – intended for a user interested in the relationships between architecture and perspective [Gutiérrez de Ravé et al, 2016] and not necessarily present in the church, but simply standing in front of the treatise or one of its reproduction – is to reinterpret the crucial mix between design and representation, between the actual work and the treatise, between architecture and perspective. It is an invitation to reflect on Pozzo's fundamental contribution to the definition of an illusory game that continues to be a powerful emblem of the instruments used in the Baroque to create works of art (Fig. 3).

The Perspective Etching

In the table shown in figure 1 Pozzo presents the barrel vault with lunettes of the presbytery and the apse in a central perspective view. The true complexity of the drawing is revealed when one notes that the vaulted surfaces of the real architecture here perspectively represented are decorated with images that are in turn perspectives, transporting the observer in a sort of half-space where the perspective multiplies in a crescendo of perspective bravura. The real architecture of this part of the church is put in perspective, as mentioned earlier, based on the way it is described in the text and portrayed in the drawing in figure 82 of *Part Two* of the treatise (Fig. 2) showing the plan cut along the axis of symmetry and the vertical section; elements that suffice to create its perspective projection.
Instead, as concerns the illusory architecture that appears in the perspective (figure 81, *Part Two*), Pozzo provides no indications regarding its true form: in actual fact this is the only occasion when, amongst all the designs Pozzo realised in St. Ignatius and described in the treatise, the illusory architecture is not provided as an addition and complement to the real architecture, as if it were an architecture that was indeed present beyond the surfaces on which it was to be frescoed. In the other tables with indications about how to create these perspective frescoes, the architecture to be "added" is coupled with that of the architectural environment and which, once built, will act as an enlargement. Instead in the etching of the apse, the metric-dimensional indications refer only to the real architecture, while the perspective image describes the environment "augmented" by the presence of the illusory component.
So, once again, the etching appears to represent a Baroque hyperbole, in line with the customs of its inventor, in which a space, whose design he shares with the reader, is placed in perspective and then used to support additional perspective projections on these represented surfaces. This game of references suggests that Pozzo comprehensively studied the construction methods and the unitary (or non-unitary) nature of the perspective construction between the two symbiotically juxtaposed components: the perspective of the real architecture and the perspective of the illusory perspective.
The perspective deconstruction tends to not only ascertain the internal orientation of the image in relation to the real architecture, but also to establish whether it coincides with that of the illusory construction. If, in fact, Pozzo conveys the best position from which to observe both the vault of the nave and the fake dome (indicating a spot on the ground corresponding to the centre of projection), he does not suggest the same spot for the apse.

Perspective Decoding

The act of perspective decoding takes place on two levels, separately tackling the perspective (real architecture) and the perspective of the perspective (illusory architecture). Figure 4 shows the convergence of all the straight lines perpendicular to the picture plane; the ones belonging to the real architecture (red) and those belonging to the virtual architecture (blue). It is easy to verify the convergence of all the lines orthogonal to the picture plane towards the same main point O_o through which the vanishing line of the horizontal

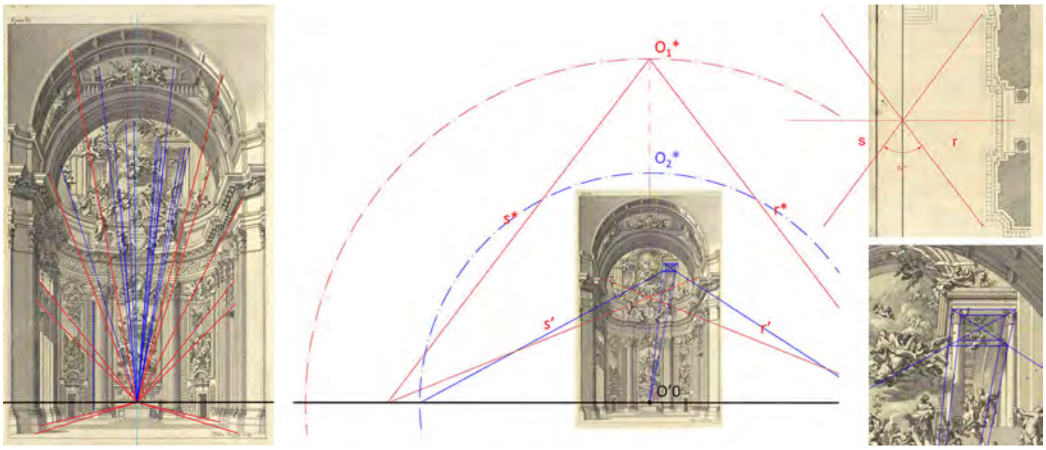


Fig. 4 Perspective decoding of figure 81, Part Two, in Pozzo's treatise [Pozzo 1700], examined using two reference systems: in red, analysis of the real architecture; in blue, analysis of the illusory architecture.

planes will pass. The horizon, at roughly 2.21 m from the floor, is rather high when compared to the height of an observer standing in the church; the fact Pozzo usually uses a viewpoint that is higher than a standing obsever is also confirmed by the position of the centre of projection imagined for the great vault of the nave [Mancini 2021].

To complete the orientation of the two perspectives (of the real architecture and illusory architecture) we have to establish the distance of the observer (or two hypothetical observers, if they do not coincide) from the picture plane, so as to position them inside the space of the church.

For the real architecture we can use the plan (Fig. 2) in which it is possible to identify two straight lines *r* and *s* that form equal angles, but in an opposite direction, with the lines orthogonal to the picture plane *x*, and measure the angle between the two (Fig. 4, top right). Having also established in perspective the straight lines *r'* and *s'* (obviously more visible at the top, at the level of the moulding), it is possible to determine the vanishing points on the horizon. The rabatment in true form around the horizon of the horizontal projecting plane allows us to draw the directions *r** and *s** that form an angle equal to the one measured in the plan (74°). Due to the symmetry of the construction, these two rabatted straight lines meet in point O^* that belongs to the vertical straight line drawn through O_o which is the rabatment of *O* on the picture plane. The main distance is identified by segment O_oO^*.

This operation is quite simple for the real architecture, but less so for the illusory architecture since, as mentioned earlier, we have neither its true form nor true measurements. We can, however, identify an element whose geometry can undoubtedly be interpreted as that of a square in the architectural span painted on the right side. At this point we can draw the diagonals of the square and thus establish the two points of distance of the "blue" perspective, the one relating to the fresco (Fig. 4, bottom right). Although they are symmetrically positioned compared to O_o, they do not establish a main distance coinciding with that of the perspective of the real architecture.

In this case it would seem possible to identify a duplication of the centre of projection: the observer of the "red" perspective (real architecture) is further away from the picture plane that the observer of the "blue" architecture.

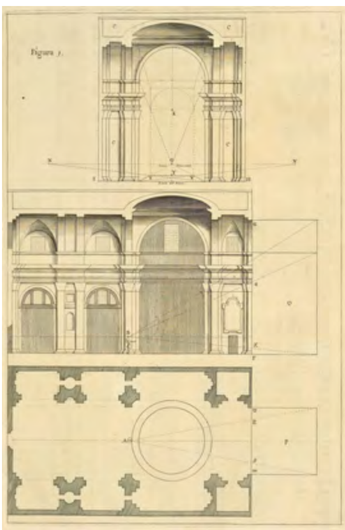
At this point we have to ask ourselves where this picture plane should be placed in the space of the church, portrayed by the digital model, given that Pozzo provides no indications.

The tables Pozzo inserts in the treatise – e.g., figures 1 and 15 in *Part One* (Fig. 5) – come to our aid; they explain how to create the perspective based on the "enlarged" plan and section, i.e., where the illusory architecture is also included. These tables reveal a sort of "routine" that Pozzo uses to construct the perspective on a plane corresponding to the centre of curvature of the apse, on the line separating the apse and the presbytery.

After verifying the position of the picture plane for St. Ignatius, we established the position of the two centres of projection O_1 and O_2, which are distant from one another but are both positioned along the axis of the church, in the space of the nave (Fig. 6).

Augmented Reality

Now the question is: how can we insert the data acquired during the previous study phases in an AR application and thus successfully communicate the unitary value of Pozzo's design and, at the same time, optimally exploit the potential provided by the selected digital system?
There are several important contents that have to be "added" to the page of the treatise; however we decided that in this experiment we would involve the three-dimensional model, the data of the perspective decoding, the model of the illusory architecture, and a comparison between the architecture represented in the table of the treatise and the real architecture built in St. Ignatius.
The target, i.e., the image activating the technology, plays a key role in AR applications. To study particularly successful perspective images the latter can be used as targets so that the user consciously perceives the perspective mechanism.
Scanning the page of the treatise with a device (smartphone or tablet) makes it possible to place the perspective inside the model of the architecture, corresponding to the position previously established for the picture plane.
Apart from the three-dimensional model, shown in section (Fig. 6) so as to facilitate exploration, one can also insert the perspective system: for example, it is possible to simultaneously place and visualise, in the same space, the "blue" observer of the frescoed perspective standing on a pedestal in order to emphasise his unusual height. It is also possible to materialise in space the "blue" perspective, characterised by its fundamental elements such as the horizon and the circle of distance, and highlight the square element that allowed us to decode the perspective. By doing so the AR user draws closer to all the features of the perspective, i.e., its spatial and two-dimensional features. The user can also verify the objectives of Pozzo's illusory design in relation to real space and review the choices made by the creators of the application.
A lot of different data has to be inserted into the system, which is why we chose to work inside the application, selecting different kinds of interactions. Our choice was not dictated only by our interest in testing the limits and potential of this technology, but also by the need to involve the user as much as possible in the exploratory experience.
Apart from the different interactions and contents, other aspects had to be taken into consideration in order to try and optimise the way the application worked.
First and foremost, as mentioned earlier, the position of the target/picture plane has to be established; it was placed between the apse and the presbytery. This hypothetical position has enormous consequences during the set up: in fact, due to the way in which virtual reality is configured, the model is always visualised "in front of" the target. In this case,



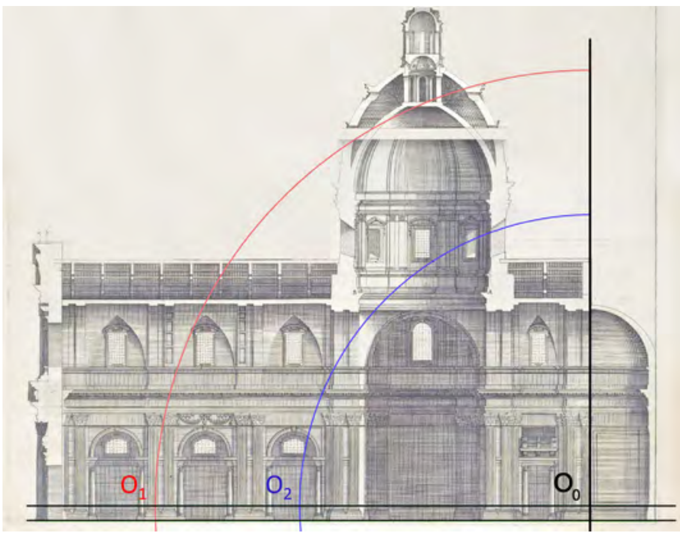
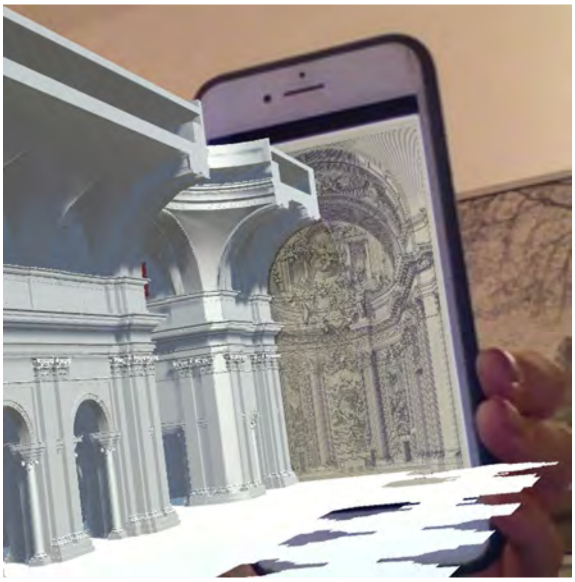


Fig. 5 Pozzo 1693, Part One, figure 1 [Pozzo 1693].

Fig. 6 Positioning of the centres of projection and the picture plane in the longitudinal section of the Church, obtained by developing figure 94, Part One [Pozzo 1693].



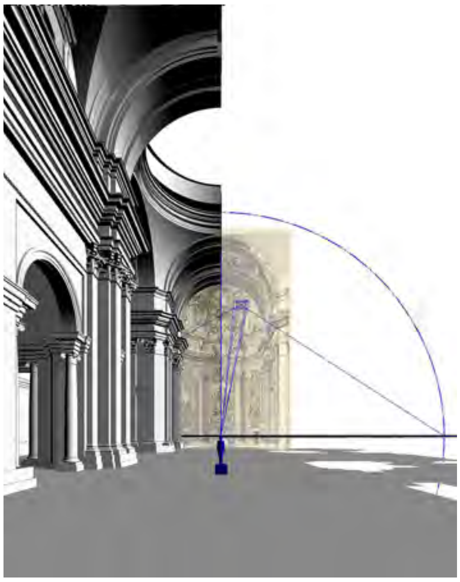


Fig. 7 Model and treatise page projected in the AR application.

Fig. 8 Observation of the additional content system as seen from the actual architecture projection hundred.

Pozzo's table (the activation element of the AR) would be hidden by the model. To solve this problem, all that needs to be done is to insert, inside the system of added contents, a second copy of the page of the treatise, placed in the same position as the target, so that the perspective image, representing the target but also the element activated by the target, remains visible when the application is launched (Fig. 7).
The three-dimensional model of the architecture was built, together with Matteo Flavio Mancini, by extracting data from figures 93 and 94 in *Part One*, showing the whole church, and also from figure 83 of *Part Two* (Fig. 2) which instead provides a detailed description of the apse and presbytery and is much closer to what is represented in the perspective table (Fig. 1). The model of the illusory architecture, obtained through the perspective restitution operated by O_2, is then "added" to the 3D model.
The architectural order and decorations have to be simplified when creating the model so that the application can be used dynamically and interactively [Russo 2021]. The syntax of this schematisation is provided by Pozzo himself; in line with the didactic intent of his treatise he often used simplified drawings before providing a detailed description of his architectural models. This critical step is necessary because the objective is not to imitate reality but facilitate the interpretation of the illusory and perspective design of the ensemble.
Another element we intend to implement is the role of the virtual camera as the centre of projection. The idea is to create perspective constructions that are activated close to the multiple centres of projections established by Pozzo. This makes it possible to reconcile the role of the kinetic camera, a characteristic of AR, with the static viewpoint of the perspective.
Operationally speaking this means exploiting the algorithms that have already been studied: using a collider the virtual camera must become an activation element so as to "switch on" (close to the centres of projection) the relative perspective decodifiers, continuing to associate, in a continuous comparison, the model, the treatise, the perspective simulation, and the projective construction that generates it. To obtain this result suitable solutions have to be identified; the latter are present in advanced studies regarding Real Time visualisation, but have not yet been verified when coupled with AR.
Yet another issue exists regarding activation buttons. The latter can be associated with a range of comparison options. It is interesting to immediately relate the treatise, where the perspective etching is present, and real space, with its architecture and decorations, both described in the perspective table. Finally, it is also interesting to compare the two elements so as to verify if the system is coherent from its ideation to its construction, and from its development to its successful illusory power (Fig. 8).

Conclusions

Ours was a privileged study because we were able to examine several drawings by the artist who painted the frescoes that reproduce the information contained in the etchings. It was a deliberate choice because it exemplified a methodology intended to link the drawings, paintings, approaches, and decisions regarding the perspective design invented by Andrea Pozzo. By emphasising the perceptive and educational value of the pages of the treatise and physical reality, the AR is not only an instrument destined to communicate the artwork, but also acts as a genuine support for the scientific study.
Any further study could use the same method to analyse other parts of the treatise, for example the ones dedicated to the fresco of the vault of the nave and the canvas of the fake dome.
In addition, our cultural heritage includes other old treatises on perspective; the procedure described here could also be applied to those treatises, thus triggering greater understanding of projective principles and the construction of perspective images placed on walled surfaces. The ultimate goal of this type of approach to research is an awareness that the drawings and pictorial works, based on said drawings, are inspired by just one idea: that of a meaningful architectural project.

Attributions

While sharing what is expressed in the contribution as the result of common reflections, the drafting of the paragraphs *Introduction* and *Representation as the activation target of the AR experience* are to be attributed to Marco Fasolo, the paragraphs *The perspective etching* and *Perspective decoding* to Laura Carlevaris, and the paragraph *Augmented Reality* to Flavia Camagni. The *Conclusions* were obviously jointly written by the three authors after joint discussions.

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Filippo Farsetti and the Dream of a Drawing Academy in Venice

Eric Genevois
Lorenzo Merlo
Cosimo Monteleone

Abstract

After visiting Rome in the mid of XVIII century the Venetian nobleman Filippo Farsetti decided to establish in Venice a Drawing Academy. For this purpose, he commissioned the duplicates of the most important ancient and modern works of art so that young artists could train copying them. First, Farsetti exhibited his collection of plaster copies in the largest rooms of his palace on the Grand Canal; later, he decided to transform his mansion into a real Drawing Academy. Farsetti asked the most famous architect of his time, Charles Louis Clérisseau, to design a project for the transformation of his palace; it, however, will never be realized.
Considering the noble didactic purpose of Farsetti and the artistic value of Clérisseau, we performed a virtual reconstruction that attempts to give a digital life to the Drawing Academy. In particular, the 3D model, the virtual images and movies are going to be used to promote and disseminate the artistic and architectural heritage of Venice [1].

Keywords
drawing academy, Filippo Farsetti, Charles-Louis Clérisseau, 3D model.

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The Birth of a New Drawing Academy in Venice

In the middle of the XVIII century, after the main archaeological discoveries that triggered an intense cultural debate, Johann Joachim Winckelmann and Anton Raphael Mengs founded in Rome a new art movement, the Neoclassicism. These two scholars believed that art should follow precise rules to achieve perfection and, according to them, such rules had already been discovered and put into practice by the ancients. From these considerations the need to train artists through the study of ancient's works arose. Thus, it happened that the Academies, the designated places of learning, collected *exempla* to copy from a glorious past to train young students [Cioffi 2015, pp. 32-39].

The Venetian nobleman Filippo Farsetti, a rich and erudite man, decided it would be appropriate to provide a similar apprenticeship for artists in his homeland. For this reason, he commissioned the copies of the main works of art realized by ancient artists as well as the works of art created by the modern artists, as Michelangelo Buonarroti, Raffaello Sanzio, Gian Lorenzo Bernini, Guido Reni who had adhered to ancient's teachings.

Upon his father's death in 1733, Filippo Farsetti inherited a huge estate and the noble title. As often happened to the Venetian patricians, he too was called to hold public office; thus, from April 1734 to April 1736, Farsetti was appointed *provveditore sopra dazi* (superintendent of duties). He realized, however, that these political commitments limited his freedom, indeed he would have preferred to devote completely his life to study. Therefore, we should not be surprised that, when in April 1736 he was appointed *podestà* (governor) of Feltre, a role that would have forced him to leave Venice, Farsetti refused the assignment and, for this reason, he was banished for three years by the *Serenissima* Republic of Venice. Following this ban, Farsetti went to Paris where he was part of Louis XV's Court [Vedovato 1994, pp. 87-91].

As soon as Farsetti came back to Venice, he was proposed for other public offices, which he refused. This time Farsetti took refuge in Rome, where, between 1745 and 1749, he renounced the noble title to become abbot with the aim to resolve definitively his political *impasse* [Vedovato 1994, pp. 95-96]. Indeed, this new condition had two advantages: it did not provide for votes or particular obligations in the religious field and, in addition, it allowed Farsetti to be permanently exempted from any type of public office of the *Serenissima* [Brunelli Bonetti 1942, pp. 93-114]. In the papal city, Abbot Farsetti met and befriended important figures of the Roman court, such as cardinals Girolamo Colonna, Andrea Corsini and the Pope's secretary Silvio Valenti Gonzaga, as well as important artists and writers including Winckelmann [Vedovato 1994, pp. 44-48]. While he was living in Rome, Farsetti participated in the great cultural debate, which leaded to the birth of a new artistic movement: Neoclassicism. In a century in which every aspect of reality had to mirror the reason, even art had to do the same. Scholars thought that art should adhere to precise rules, which revolved around the concept of beauty. In particular, Neoclassicism was born in contrast to the Baroque and Rococò, which in the eyes of the new artists were governed by capricious choices, far from scientific rules, rigor and canons. According to

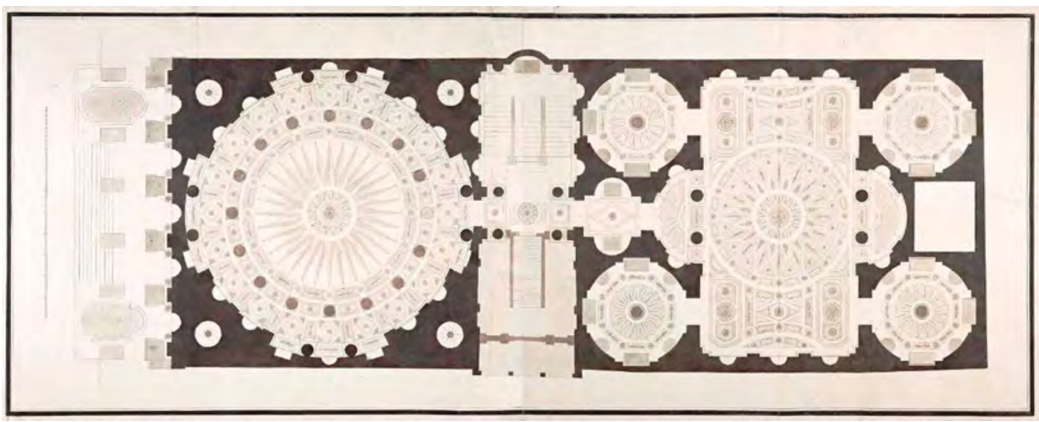

Fig. 1. C. L. Clèrisseau. Plan for the Drawing Academy Project, 1764.

this idea, the discovery and application of rules would lead the artist to the creation of the perfect work. Searching for these artistic canons, it was soon clear that some specific rules had already been discovered and applied in ancient times, as evidenced by some works, examples of perfection and ideal beauty [Larson 1976, pp. 390-405]. To discover the rules of beauty, it was sufficient to study the works of art of the ancients and those of modern artists who had followed their teachings. For this reason, it was essential to renovate the academies of fine arts, basing them mainly on the study of the works of the past. So, the academies became places where students could practice through drawing the precise outline of bodies following the correct proportions of single parts.
Farsetti had the idea of promoting a new Drawing Academy in Venice, hoping that the government of the *Serenissima* would have arranged for a suitable place. He thought to contribute mainly with the base material, providing plaster copies of the most important ancient and modern artworks preserved in the museums, palaces and churches of Rome. Farsetti realized soon that it would have taken a long time before the Venetian government built a new Drawing Academy, so he decided to temporarily host his collection of plaster sculptures and other works of art in his palace on the Grand Canal, allowing anyone to visit his house and, in particular, students. Initially the collection occupied only some rooms on the noble floor, but with the increasing of the works, it was everywhere, as evidenced by the French economist and politician Jean-Marie Roland who visited the palace in 1777: "[...] toutes les pièces du premier étage en sont remplis", adding: "La collection est la plus complette que je connoisse" [Roland 1780, pp. 43-44]. A register, dating back to 1775, of the artistic works exhibited at Farsetti's palace [2] testifies that the pictorial copies have been lost, while a good part of the plasters sculpures still exist and are preserved in Venice, at the Gallerie dell'Accademia, and in Bologna, at the Academia d'Arte and the Liceo Artistico Statale.
Since the government of the *Serenissima* did not seem interested in establishing a Drawing Academy, Farsetti decided to modify his home and entrusted this task to one of the most famous architects and artists of his time: the Frenchman Charles Louis Clérisseau. This project was never realized, but recently the Getty Museum in Los Angeles bought a Clérisseau's plan drawing, relating to the Farsetti project (Fig. 1). Although no other drawings have been discovered, Clérisseau's plan for the Drawing Academy contains a sufficient number of information to virtually develop a hypothetical model of its design. Not having elevations and sections, we were forced to formulate some hypotheses. Since it would take too long to explain all the choices made, here we want just to underline that, to anchor our conjectures to facts and documents, we have: contextualized our reconstruction in the theory of architecture dedicated to academies; analyzed the treaties; compared the plan of the Getty Museum with the archetypes of ancient architecture, with other Clérisseau projects, and with famous Neoclassical buildings. Finally, we added the digital survey of plaster sculptures to the 3D virtual model [Genevois, Merlo 2020]. Considering the noble didactic purpose of Filippo Farsetti and the artistic value of Clérisseau, this virtual reconstruction brings to digital life the project of the Drawing Accademy, with the aim of promoting and disseminating the artistic and architectural heritage of Venice.

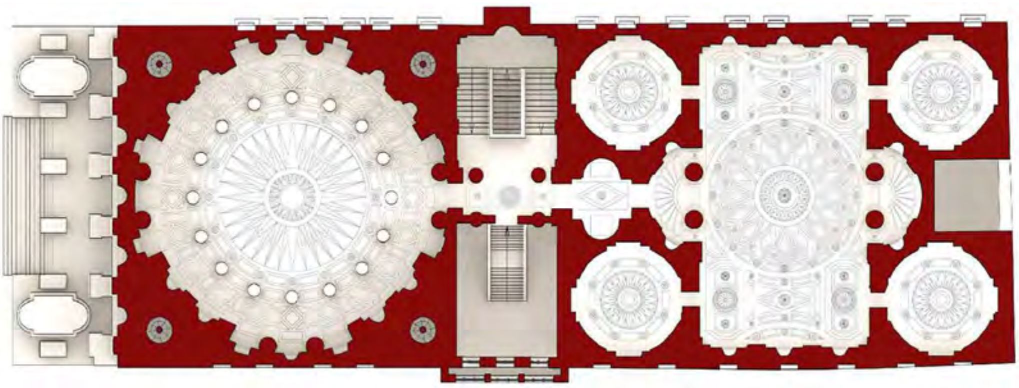

Fig. 2. Digital reconstruction of the plan for the Drawing Academy Project.

3D Reconstruction of the Farsetti's Drawing Academy

After having carefully studied the plan created by Clérisseau, after a continuous comparison with the historical literature dedicated to architecture and after having analyzed similar projects, inspired by the Pantheon or intended for analogous functions, we went on with the hypothetical reconstruction of the Farsetti's Drawing Academy.

In a first phase, the noble floor of the Farsetti's Academy was drowned with a CAD software. To obtain a vector duplicate of the plan, all the lines were faithfully traced, also following the asymmetries and imperfections between the architectural elements, in order to be able to carry out a complete analysis regarding the scale of representation and the geometric proportions used by Clérisseau. Since the concept of symmetry was scrupulously respected by artists and architects during Neoclassicism [Vettese et al. 2016, p. 23], our vector drawing was modified to eliminate distortions or inaccuracies, in order to restore absolute symmetry (Fig. 2). Clérisseau's plan of the Getty Museum is an extremely detailed graphic document realized on a large scale. From a careful analysis it is possible to establish both the units and the scale of this important drawing. Since the front of the building is 29.4 cm, comparing this measure with the real dimension of the actual palace, it follows that the unit used by Clérisseau is 0.3248 m, which corresponds to the eighteenth-century Parisian foot, so the scale of the drawing is equal to 1:50. The entrance to the Academy from the water is on a wide staircase that leads to a base on which Clérisseau places 6 minor pedestals in correspondence with the pilasters, and 2 major ones, located between the two most extreme podiums. Given the similarity, the main two pedestals have been modeled like those that support the statues of the Dioscuri which Farsetti had duplicated in plaster and flank the steps leading to Piazza del Campidoglio in Rome.

The large circular hall, which is accessed crossing the entrance door on the Grand Canal, is dominated by a huge dome reminiscent of that of the Pantheon. Eight columns are located at the ends of the median axes, while twelve pilasters have been placed at the ends of the diagonal ones. Four large niches are created in the space that connects the three sectors located at the ends of the median axes. Semicircular and rectangular niches are distributed between columns and pilasters, all having the same width, inside which the statues were to be placed. The central space shows circular pedestals to accommodate other statues and we can hypothesize that these podiums were made on wood in such a way as to be removable for greater comfort of the students.

Continuing with the virtual reconstruction of the project, we also took into consideration the stairs that allow access to the building from the public road. In this case, Clérisseau's drawing does not show perfect symmetry, because the French architect wanted to adapt his project to the existing building. For these reasons, the arrival landing appears to be the same size as today and the designed staircase reflects the dimensions of the existing staircase.

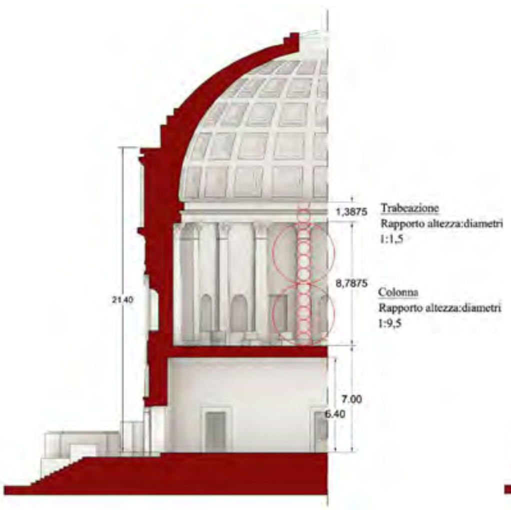

Fig. 3. Andrea Palladio's rules of the Corinthian order applied to the main circular hall.

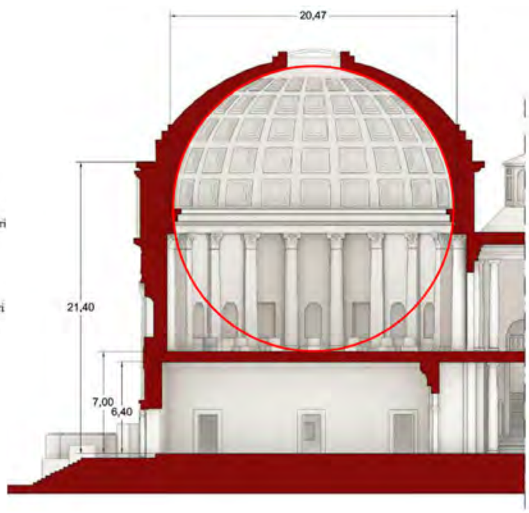

Fig. 4. Geometric matrix for modeling the dome of the main circular hall.

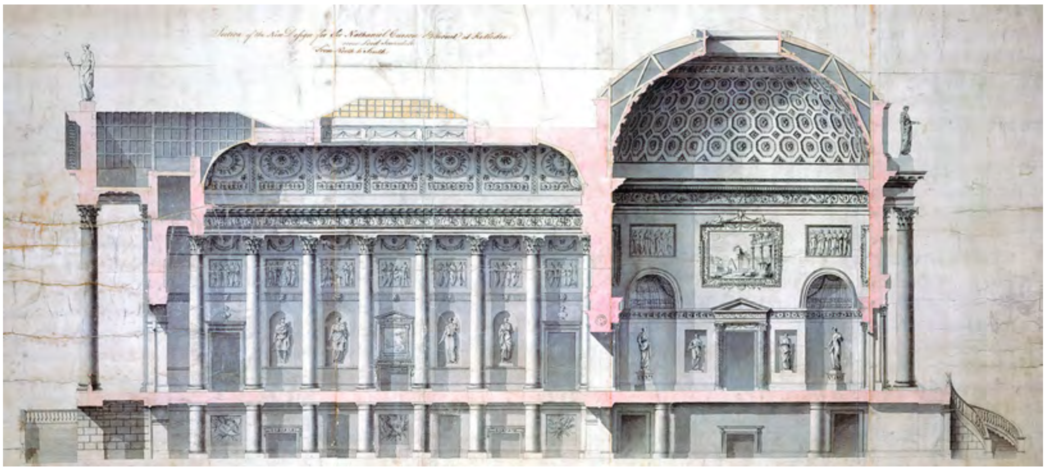

Fig. 5. R. Adam. Section of Kedleston Hall, 1759.

The remaining space of the plan (a rectangle with sides in the ratio of about 3:4) was used by Clérisseau to create a large rectangular room in the center with two anti-halls opened on its longer sides and four circular rooms at the corners. In this way he achieved a double symmetry and a variety of shapes with respect to main circular hall. About the vaulting system that cover these spaces, we can hypothesize that the rectangular hall is covered by a cloister vault with a rectangular opening of adequate size on the top to allow the light to penetrate inside, while for the two anti-halls we intended a flat ceiling, while for the four circular rooms we modeled hemispherical vaults with oculus on the top, as for the main circular hall. Finally, to carry out a faithful reconstruction of Clérisseau's project, we digitally drew also the decorations of the floor.
After the reconstruction of the plan preserved in the Getty Museum, we hypothesized that the French architect probably had no intention of demolishing the abbot Farsetti's palace that we can now admire on the Grand Canal. More simply, he could have changed and upgraded the actual configuration. In particular, Clérisseau would probably have chosen to eliminate the current roof, keeping the existing roof molding. Therefore, the heights of the perimeter walls of Palazzo Farsetti could be considered the same as those of the project for the Academy. To sketch out a plausible section, having a probable reference height available, we resorted to specialized literature and, in particular, the proportional rule of architectural orders, proposed by Andrea Palladio [Palladio 1570, pp. 15-51]. Basically, we considered the diameter of the columns at the base as the module from which to start to size all the architectural elements of the project (Fig. 3) and we went on by analogy. A couple of examples will suffice to clarify this procedure.
For instance, it is evident that one of the key features of the main hall is its striking resemblance to the Pantheon. Therefore, in the absence of an original section, some geometric and decorative features present in this ancient building have been considered as a reference, in order to reconstruct a possible section. First, we verified that the inner space could circumscribe a sphere, thus determining the height and size of the oculus that serves to illuminate the circular hall, then we created a digital coffered dome following the model of the Pantheon (Fig. 4).
Robert Adam's Kedleston Hall offered a solution for the reconstruction of the rectangular room (Fig. 5), basing on the fact that there were constant contacts between Clérisseau and the Scottish architect [Eustace 1997, pp. 743-752]. Indeed, observing the section of this building, we can find a rectangular hall covered by cloister vault that follow a circular hall, like in the case of Clérisseau design. Furthermore, given the widespread use of this type of vault by Neoclassic architects, we considered appropriate to equip with a similar ceiling the rectangular hall of Clérisseau's project and maintaining the same proportional rules used for the circular hall, because the Getty Museum plan shows equal columns in both spaces (Fig. 6). Furthermore, we opted for a coffered vault following as an example a painting by Clérisseau relating to the *Room of the Ruins* at Trinità dei Monti convent in Rome (Fig. 7). Once the restitution of the noble floor, the heart of Farsetti's Drawing Academy, has been completed, we virtually modeled the other floors. Since these spaces are intended for secondary purposes with respect to academic functions, such as warehouses, they has been created basing on the current situation.

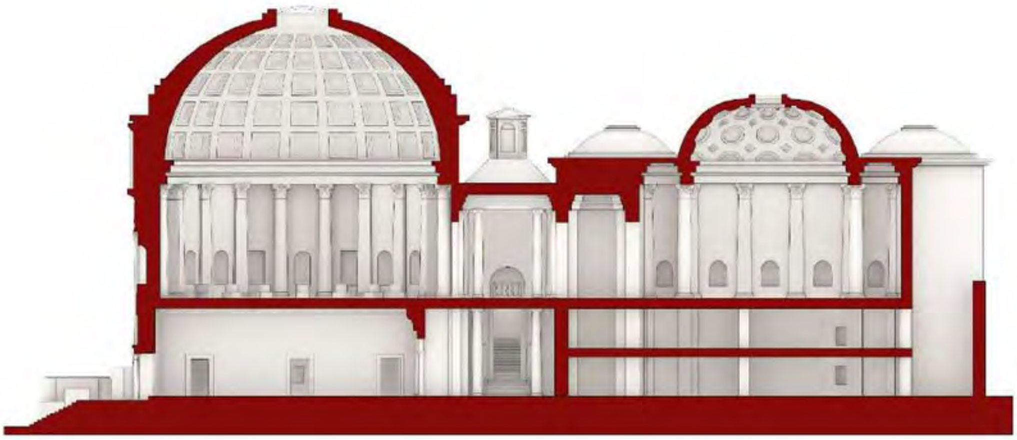

Fig. 6. Digital reconstruction of the section for the Drawing Academy Project.

The Farsetti Collection: Digital Survey and Exhibition Criteria

There is a manuscript catalog of Filippo Farsetti's collection, compiled around 1755 and later updated in 1778 [2], therefore, this document can be considered a useful reference of the situation in which Clérisseau started his design of the Academy. Part of the original Farsetti collection remained in Venice. This part is now mainly preserved by the Galleria dell'Accademia, after most of the art pieces moved between 1799 and 1800 to the Academy of Fine Arts in St. Petersburg [Noè 2008, pp. 224-269]. Luckily, copies of the collection exist also in Bologna, at the Accademia d'Arte and the Liceo Artistico Statale in Tolmino street. these plaster statues replicate some of the most important sculptures of Farsetti collection. These artworks are in Bologna because Filippo Farsetti promised to replicate sculpture also for the pope Benedict XIV, agreeing on a refund of about 6,000 ducats. The Pope later donated such plaster statues to his hometown, Bologna [Pagliani 2003, pp. 63-127].

For the arrangement of the plaster sculptures in the 3D model we selected the following spaces: main front, small passage, stairwell, circular rooms, circular hall, and rectangular hall. The statues for the front are quite certain, thanks to the analysis of the statuary that was generally proposed in art academies and thanks to the known dimensions of the niches and bases to house them. There is some certainty also for the small passage and the stairwell, as these spaces preserved their original configuration over time and the inventory of 1755 indicates some artworks located in these specific places. After the flight of stairs, entering the noble floor, there is a room oriented along the length of the building, which at its ends would have host the largest sculptures of Farsetti collection: Hercules and Flora Farnese. The same reasoning can be extended to the small circular rooms, where Clérisseau had foreseen pedestals arranged in their centers, probably to set up equally important statues. For the main circular hall, unfortunately there is not much information but, basing on the size of the niches and keeping in mind which side the statues presumably should have shown, we decided to place the medium-sized plaster sculpture, whose back has no particular relevance, in the perimeter niches, and the most important copies on the revolving pedestals. Probably, from an educational point of view, the main circular hall would have been more instructive for students, because there would have been the opportunity to sit in the center of the hall and copy the sculptures illuminated by natural light coming from above. The same distribution principles were also applied to the rectangular hall.

No doubt that Clérisseau's Academy would have been enriched by these magnificent works of art. To faithfully reconstruct the artistic world that would have surrounded the students, we performed a digital survey of the plaster copies (Fig. 8), which were then put into the virtual model. We used Agisoft Metashape software which, as is widely known, is based on the principles of photogrammetry. After obtaining the authorizations, we began the photogrammetric survey of the sculptures starting from October 28th 2020. Many hours of work were spent on the survey for an average of 200 photographs per statue. These photographs

Fig. 7. C. L. Clérisseau, Rooms of Ruins, 1766.

are well defined and very sharp, moreover the images are not distorted due to the lens, having used the optimal focal length of 50 mm and the 24x36 format [Di Bello 2018, pp. 2-3]. Since the survey has been performed in the interiors of the museums place, crowded with objects, and since we were not allowed to move the plaster sculpture that usually were located along the walls, the photographic shots did not entirely cover the surface of the statues. Moreover, since natural lighting was not sufficient, it was necessary to add artificial lights. The operations took place without the flash, as the shadows would have changed theirs position every time, making the recognition of homologous points impossible. A reflective and uniform surface (as in the case of newly restored plaster sculptures) greatly complicated the survey operations. In all these cases it was necessary to create many frames to ensure a correct reconstruction. The shots were performed with a Nikon D7000, digital camera with a 16.9 Megapixel sensor. The sensor was set at ISO 100 for all sessions and the lens opening was set at 5.6. The file format we have chosen is the Tagged Image File Format (TIFF) also recommended by the software specifications.

Fig. 8. Digital survey of the Belvedere Torso plaster copy .

Conclusions

The work performed is an experiment of a method for the reconstruction of a unbuilt architecture, basing the outcome on literary and artistic sources related to Filippo Farsetti, Charles-Luis Clérisseau and the Drawing Academy. Given the importance that Clérisseau's design, if realized, would have had for the history of art and architecture in Venice, we broaden the research to other contemporary Drawing Academies of the time and to the works of other architects such as those by Robert Adam. The extension of the analysis to similar projects made it possible to justify some of the most important choices in our 3D reconstruction, such as those of the vault system and the orders of architecture. Our virtual model cannot obviously consider itself scientifically equal to Clérisseau's design, which was handed down to us only thanks to the plan preserved at the Getty Museum but our purpose is to evoke the neoclassical idea of a public building with educational aims addressed to young artists. However, although hypothetical, since each of our reconstructive hypothesis is based on a precise reasoning, anchored to historical-architectural sources, this 3D model can still be considered plausible.
Our digital reconstruction of Farsetti's Drawing Academy is a good base for virtual and augmented reality applications. This innovative aspect of the representation appears particularly interesting, since it would allow a contemporary observer to enter the Farsetti's Academy walking through the halls of an eighteenth-century museum. The development of these technologies has advanced rapidly in recent years, increasing their applications to spread the knowledge of archaeological sites and, more generally, of the artistic, historical and cultural heritage. In our case we are in the process of developing, basing on the 3D reconstruction of the Drawing Academy already performed, virtual and augmented reality applications for 3 important institutions interested in this topic and in the dissemination of the cultural heritage that they preserve: the Gallerie dell'Accademia and Domus Grimani in Venice; Villa Farsetti, owned by the municipality of Santa Maria di Sala in the province of Padua.

Notes

[1] The author of *Abstract, The Birth of a New Drawing Academy in Venice* and *Conclusions* is Cosimo Monteleone; the author of *3D Reconstruction of the Farsetti's Drawing Academy* is Lorenzo Merlo; the author of The Farsetti Collection: Digital Survey and Exhibition Criteria is Eric Genevois.

[2] *Inventario di tutte le statue, busti, modelli, bassirilievi e quadri della galleria Farsetti*. Biblioteca Universitaria di Padova, MS. 1997.

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AR to Rediscover Heritage: the Case Study of Salerno Defense System

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Abstract

Recognizing and transmitting the uniqueness and identity of one's territory represents fundamental step to guarantee its sustainability, protection and valorisation. Of particular importance, moreover, is the issues of the lesser-known heritage of great value but which, unfortunately, in some cases is still little known and often in a state of neglect. However, the diffusion of new technology and the great development of digitization positively contribute to the accessibility and visibility of these patrimonies, increasing the knowledge and the dissemination. This contribution focuses on one of the towers of the coastal defence system, a perfect example of a lesser-known architecture of great interest to be valued. Through a multidisciplinary approach, which inextricably links history and new ICT applications, it will be possible to improve the knowledge of the heritage, enriching with complementary information that goes beyond the simple geometric definition of the building: an important tool for protection and preservation mainly for informative purposes.

Keywords
photogrammetry, 3D model, towers, virtual reconstruction, HBIM.

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Introduction

Currently, the implementation of Augmented Reality (AR) is a widely investigated issue in various fields [Mekni and Lemieux 2014, pp. 206-210], as well as in cultural heritage [Merchán et al. 2021, pp. 6-10; Vitali et al. 2020, pp. 60-61] that, together with Virtual Reality (VR) and Mixed Reality (MR), could be used for different purposes such as for education, exhibition, exploitation, reconstruction, or Virtual Museum [Kassahun et al. 2018, 7:16, 7:17]. The use of AR, in fact, has proven to be an excellent aid to improve tours of museums, archaeological sites or monuments, increasing the curiosity of visitors and enriching their knowledge. Furthermore, these innovative methods allow us to go beyond the real world and overlay what we see with additional information and data, ensuring a new perception of the space and the architecture [Russo 2021, pp. 24-28]. The approach also becomes more engaging with immediate images and details that improve communication even with non-expert audiences. Operating in this way, it is possible to virtually re-built heritages now partly or entirely lost [Cannella 2021, pp. 121-122] and access to more information (tangible and intangible) both of already known monuments and, as in the case study, for buildings widespread on our territory of which, however, we often pay little attention.
In this contribution, we focus on the towers of the coastal defence system of Salerno; in particular, we dwell on a single tower to retrace the historical events that have characterized it and enrich the view of the structure with a series of additional information. The workflow adopted has foreseen both a knowledge phase of historical investigation and a more practical one: starting from the photogrammetric survey, it was possible to generate a point cloud to be used as a basis for the three-dimensional modelling of the tower. The comparison with the model developed by the photos taken before the restructuration and the documentation collected has allowed, instead, to partially restore the initial conformation of the building and the organization of the interior. The reconstructive hypothesis also concerned the surrounding area, foreseeing an immersion in the past, capable of bringing to life, through AR, the historical settings, and allowing a greater understanding of the strategies of defence from the sea. This goes along with the current concept of Digital Twin (DT): the virtual representation of a physical entity, alive or not, of a system, even complex. The digital component is somehow connected with the physical part, with which it can exchange data and information, both synchronously and asynchronously. The DT evolves to become a digital replica of the potential and actual physical resources, processes, people, places, infrastructure, systems and devices that can be used for various objectives [Gabellone 2020, pp. 232-234].
The purpose of this contribution is to enhance little-known heritage through the use of ICT (Information and Communications Technology), a streamlined and effective process with mainly informative and divulgate purposes aimed at motivating the curiosity of travellers. The study of the Torre dell'Isola could be paradigmatic for other buildings located along the coast and lay the groundwork for future developments with the aim to encourage and increase the knowledge of our heritage.

The Case Study: Brief Historical Description

Traveling along the coast of the city of Salerno, one comes across a multitude of towers that have always fascinated travellers, projecting them into a remote time. Over the years, the coastal area has been subject to several raids, especially by corsairs; in this regard, the need to protect and defend the territories led to the construction of a series of towers along the cost with the aim to ensure warning signals and allow the organization of an adequate counter-offensive. However, if at the beginning it was an approximate plan, over the years and under the various dynasties a precise and well-planned strategic system was defined. Around the middle of the 16th century, in fact, it was possible to identify an efficient sighting system with the aim to monitor the entire coastline [Pignatelli 2007, p. 301].

The organized defence plan was a real network of “gazes” to observe and monitor the entire coast. The choice of location of the tower was not only linked to its accessibility or the presence of passable roads but was also the consequence of careful studies by a group of technicians, strongly influenced by the visual relationships existing between one tower and another [Talenti and Morena 2016, p. 173]. Each of these towers represented a strategic point of the entire system; in fact, its precise location guaranteed a visual connection. The network of views, therefore, was the fundamental element of the project, which is why the individual tower should not be seen as a single element but as an integral part of a larger project. Hence, it is necessary to know and preserve each individual building to prevent the disappearance of one of the most ingenious works of all time.
Torre dell'Isola, the case study, is located along the road Cavallara in the current municipality of Camerota and owes its name to the small island located in the front [Santoro 2012, p. 255]. Its construction had probably already begun in the second half of the 15th century, as there are documents that attest to the presence of custodians in 1599 [Vassalluzzo 1969, p. 171]. The dimension of the slender tower is assumed to derive from its function of sighting [Santoro 2012, p. 255]; as usual, in fact, these types of towers were taller but did not have thick walls since they were located in strategic positions and were hardly exposed to attacks [Russo 2009, p. 206]. Risen with signal function, in the past, it guaranteed visual connections with the surrounding towers; today, the presence of new buildings hinders the ancient network. Subsequently, in 1776, the garrison of the same was assigned to the military invalids [Russo 2001, p. 274] and, following the decree of Vittorio Emanuele II of 30 December 1866, the building lost its function of fortification and was subject to trading. Despite its fascinating position, the tower object of study had been completely abandoned over the years. Around the eighties of the last century, in addition, the tower was subjected to a series of changes: the elimination of interior spaces through the demolition of floors and the reduction of wall thicknesses [Santoro 2012, p. 256]. This situation, therefore, contributed to make the tower more unstable, increasing its situation of precariousness and abandonment until 2018, when the tower was restored, assuming its current conformation.

Photogrammetry Survey and Post-processing

To virtually re-built the original state of the tower inevitably requires an initial phase of data acquisition to retrieve supporting information for the 3D model. To this purpose, after initial historical research, was followed a quick survey using close-range photogrammetry. Two models were developed, the first based on the current state of the tower and the second on the conditions before restoration.

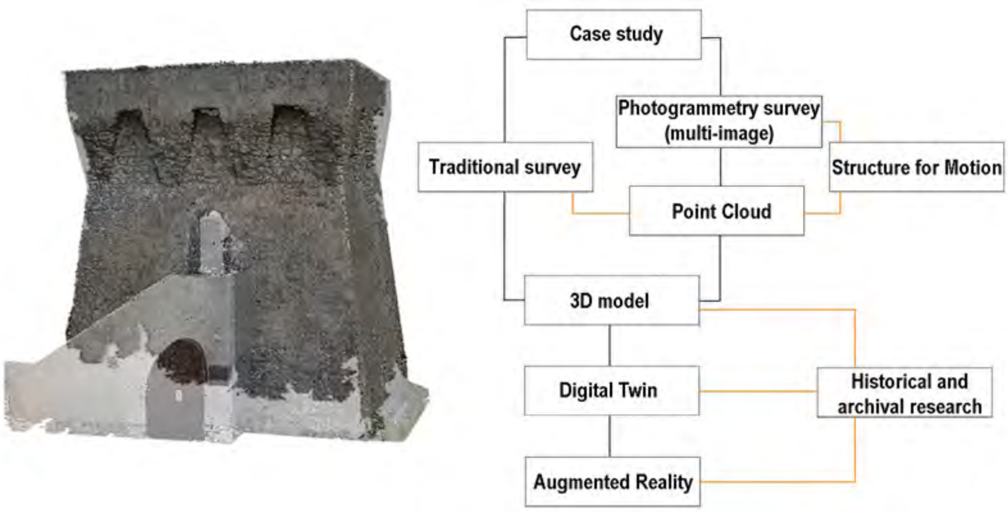

Fig. 1. Overlay between the pre and post restoration photogrammetric model and general workflow.

The photogrammetric survey of the former case was achieved with a single-lens reflex camera Nikon D5300 with 24 Megapixels CMOS APS-C (23,5 mm x 15,6 mm). Given the dimension of the building, the photos were acquired in portrait orientation, setting fixed focus and with a focal distance of 18 mm. The images were taken around the tower with an aperture of f/8, shooting frontal and tilted pictures and trying to ensure proper overlap and a constant distance from the object. The data acquired were thus processed in Agisoft Metashape, following the typical photogrammetric workflow. The generation of the Tie Points was obtained by aligning 240/240 photos with around 97.700 points. Before proceeding to the generation of the Dense Cloud, however, we decided to remove the Tie Points characterized by low quality in order to recalculate the parameters of the orientation, by setting the values of Reconstruction uncertainty, Reprojection error and Projection accuracy [Antinozzi 2021, p. 216]. The process was concluded by scaling the model and generating a Point Cloud of about 16.750.000 points to be exported in .e57 format.
Similar procedures were used for the 15 photos before restoration, although they were taken without a planned capture set. Camera used is a Canon EOS 1200D with an 18 Megapixel CMOS APS-C (22,2 mm x 14,7 mm), but the pictures were acquired without fixed focus and different apertures. Nevertheless, the generated Point Cloud has allowed us to compare the pre and post-restoration and analyze, at least externally, some elements such as embrasures and position of the staircase and the opening (Fig. 1). In both cases, since the tower is located near a cliff, the main problems were encountered in the survey of the southwest façade, that was not surveyed. Observing the elaborated models, it can be noticed how typologically it is identified as a tower with three embrasures [Russo 2009, p. 180] with a square plan and dimensions of about 11 x 11 m. The basement develops with an oblique trend, making the tower assume the typical truncated-pyramidal confirmation necessary to carry out both static and war functions.

Reconstructive Hypothesis

It has been possible to reproduce the initial geometric conformation of the tower in a digital environment, using the photogrammetric survey as a base, while for the interior, as well as for the parts that are now lost (as in the case of the staircase), we have proceeded respecting the qualitative characteristics in the absence of precise metric data.
The BIM (Building Information Modeling) of a building with historical value becomes a valuable tool for the preservation and enhancement of the built heritage, allowing the digital revisiting of the history of the building. The point cloud then formed the basis for generating a three-dimensional model in the Revit environment (Fig. 2). SketchUp Pro software was used to locate the topographic surface. Starting from the geographical coordinates of the site, using geolocation, the topographic surface was detected. To obtain the contour lines from this mesh, sectioning it with parallel and equidistant horizontal planes was necessary. The contour lines thus obtained were exported in .dwg and imported into Revit to recreate the topographical surface. The 3D model was created in Revit, an object-oriented parametric modelling software.

Fig. 2. Scan to BIM. From left to right: point cloud with an overlaid BIM model, BIM model of the tower after restoration and BIM model of the inizial configuration.

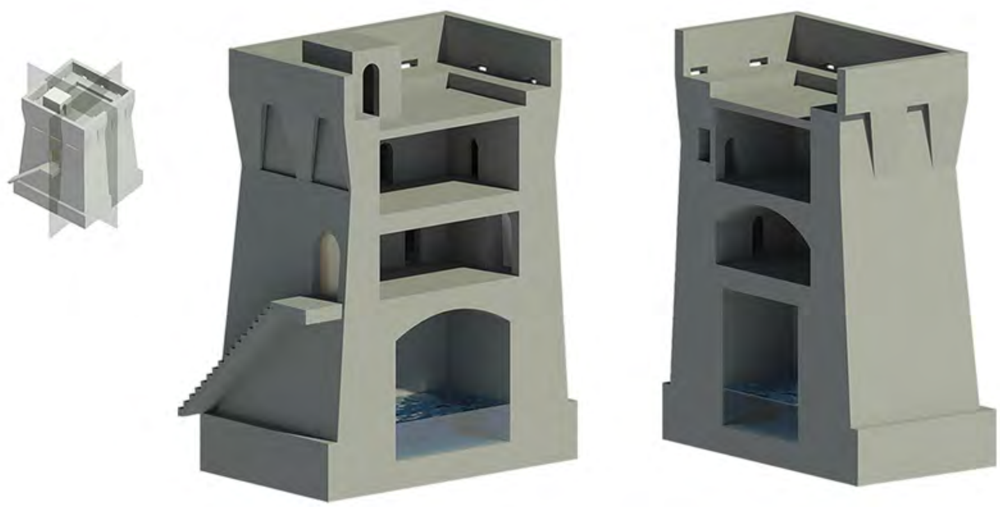

Fig. 3. Representative BIM model of the initial Torre dell'Isola configuration hypothesis.

This type of architecture is rarely suitable for modelling from standard objects because each element is unconventional and challenging to parameterize: the tower was digitized by breaking it down into several objects, rather than by creating masses [Guida 2021, p. 1022]. Given the unconventional shape of the geometry, the subtraction of solids and voids was used.
The modelling of the tower focused not only on the purely geometric aspect, but, above all, on the informative and semantic aspect of the same, intending to study in-depth and understand the evolutionary phases of the same, accompanying the model with historical information, archive documentation and photos. The point cloud helped to shape the exterior of the building while traces were still visible; photographs and historical documentation led to this original conformational hypothesis (Fig. 3).
Based on previous studies, bibliographic references [Vassalluzzo 1969, p. 48; Aversano 1976, p. 398] and traces found on the building, it is supposed that this tower was developed on three levels. A barrel vault covered the ground floor, it had a cistern function and was characterized by an independent access on the East side of the building. The second floor, probably also covered by a vault, but developed in the opposite direction, was used for the guards' lodgings and, most likely, a third floor above which was placed the square with the typical sentry boxes [Aversano 1976, p. 396].
The upper floors are presumed to be connected to each other through internal stairs, while the first floor had a single entrance accessible by means of a masonry staircase located near the mountainside, whose trace is visible on the pre-restoration model. The latter, moreover, confirms the hypothesis of plastered towers also on the outer face and makes visible the underlying masonry, made of local stone arranged in overlapping bands of about 60 cm, where the typical leveling made with thick layers of mortar are present [Santoro 2012, p. 257].

Augmented Reality

The implementation of AR in this case study aims to develop an application that allows people to rediscover the history and past of the tower. For example, walking along the ancient Cavallara road, one could frame the tower with one's smartphone or tablet and access a series of informative and historical information. In fact, with the increase in technological proposals and the advancement of new object modelling and visualization techniques, such as AR, VR and especially DT, the way of conceiving the representation of a real object has changed radically. In addition, with these technologies a model has been created to support an innovative concept of digital tourism, allowing visitors to organize

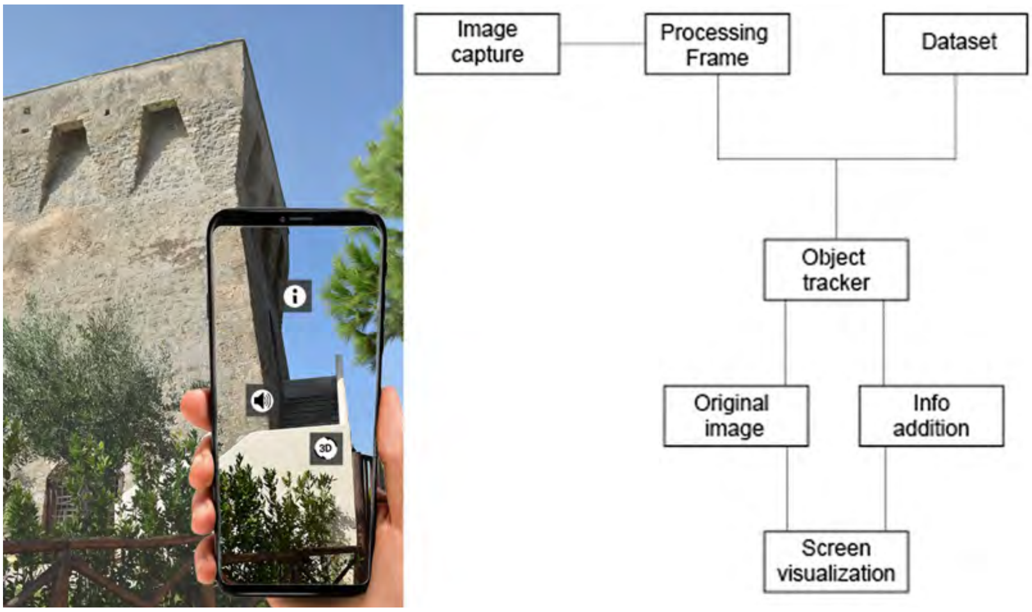

Fig. 4. Augmented reality application and workflow.

their tour experience not only in situ but also remotely, through web or mobile apps, increasing accessibility and curiosity of people.
A model based on DT paradigms was prepared to support this experience: starting from the photogrammetric survey and historical research, passing through the point cloud development to support BIM modelling [Colace 2021, p. 378]. Then, to reconstruct the setting in detail, a powerful graphic rendering software such as Twinmotion was used, it allows the creation of an immersive 3D environment easily and comfortably for experienced users. In addition, it is possible to generate new elements and new materials adapted to the needs of the representation, such as objects and costumes from the era. This software can also be used to create interactive VR videos and 360° virtual tours in 4k to improve the usability and interactivity of the object under study. This reconstruction was used as the basis for a mobile application, iOS and Android, which can exploit augmented reality frameworks to make the user visualize the reconstructed historical setting.
As a further on-site experience, the app can be interrogated through tags to dynamically acquire information by framing objects through the camera of one's smartphone (Fig. 4). This methodology can be used in various ways, for example to support educational moments in historical or artistic disciplines. The user interface between the model, the information and the mobile application was developed with a graphics engine commonly used for games, Unreal Engine, demonstrating how different disciplines interface in different applications and how the world of gaming influences architectural design by providing this type of support.

Conclusion

The process of heritage valorisation finds in ICT influential support for the development of ever inclusive and innovative methods. The new technologies, in fact, provide greater accessibility and support to increase and facilitate the knowledge of our history. Despite the complexity that often hides behind such processes, the result appears simple and immediate, promoting the dissemination and interest of heritage even to a less expert audience. Moreover, the actual possibility to share on Internet ensures the enjoyment of sites even remotely, allowing to live experiences every time and in various parts of the world, increasing the interest in fascinating places on our territory.
The present work aims to develop a dissemination process of lesser-known architecture, such as the towers of the Salerno coastal defence systems. Through the use of augmented

reality, it will be possible to bring back the past, highlighting above all the changes over time. To this end, the new technologies of representation and ICT tools, in general, can reset the distance between present and past, facilitating the understanding of buildings and their evolution over time.
Furthermore, if the discipline of surveying has made it possible to trace the forms of the tower, digital modelling has made possible to hypothesize a reconstruction and to enclose in a single infographic model the geometry and the database connected to it, fundamental elements for the knowledge and protection of the historical heritage. Finally, the use of Digital Twin (DT) has allowed to improve the interface and to restore the representation of a past function that the tower had, thus rediscovering the ancient function of sighting and the network of "gazes" that existed in the past between one tower and another.

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AR for Demolished Heritage: the First Italian Parliament in Turin

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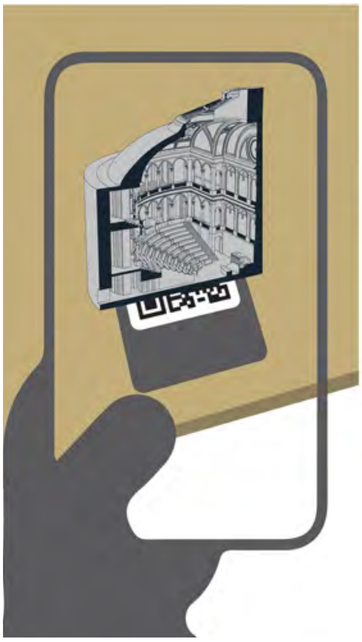
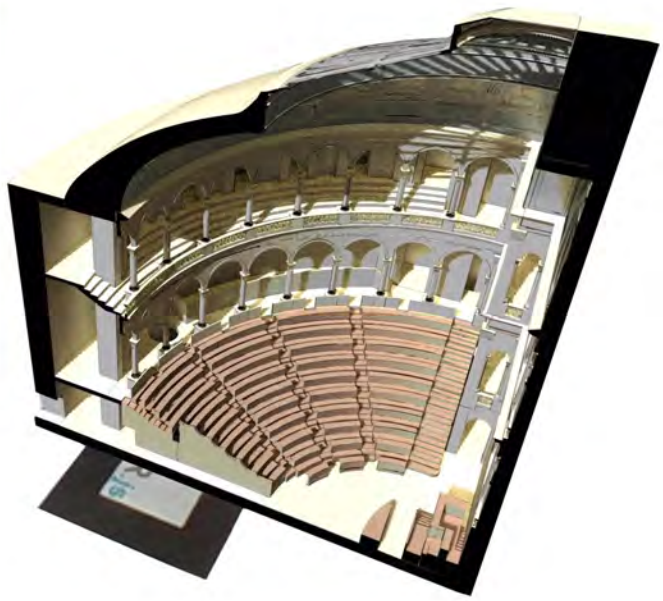
Michele Ambrosio

Abstract

This research presents a study of reconstructive digital modelling and AR application on the chamber of the First Italian Parliament located in the courtyard of Palazzo Carignano in Turin.
The study carried out in cooperation with the Direzione Regionale Musei del Piemonte, based in Palazzo Carignano, focuses on a building that no longer exists, a part of the demolished heritage that only remains in documents, archive drawings and historical studies.
The research that led to the creation of a 3D model began through a process of analysis and study of historical documents, consisting of both descriptive sources and various drawings of the architecture. The type and graphic characteristics of the sources influenced the degree of accuracy of the reconstruction, just as the type and mode of communication of this heritage affected the reconstructed digital model itself.
Through the use of AR applications, the model is to be represented and visualised in its design space, to be integrated into a larger and new virtual museum.

Keywords
demolished heritage, 3D reconstruction, archival sources, augmented reality, virtual museum.





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The Temporary Chamber of the Italian Parliament

In 1861, inside the courtyard of Palazzo Carignano, a parliamentary chamber was built in honour of the proclamation of Turin as the capital of Italy. The building, designed by Amedeo Peyron, an architect and engineer specialising in railways, was built in just three months from the end of 1860 as an extension for the building of the Chamber of Deputies of the Subalpine Parliament, which needed new space.
The semicircular chamber made of wood, iron and glass – in the courtyard of the then 17th-century C-shaped building – was only used for a short period; the new dynamics of the State have brought first to the change of Capital and, later, the new architectural requirements of the Palazzo Carignano complex led to the demolition of Peyron's building in favour of a reversal of Guarini's building to close off the courtyard.
Through the consultation of bibliographical sources such as printed texts and newspapers of the period, it was possible to retrieve various information, both regarding the structure of the chamber and its decorations. Using the archives and libraries in the Turin area, it was possible to trace the iconographic and documentary sources that made it possible to reconstruct the events that took place during the construction and the period immediately afterwards.
The chamber is set on a main structure of half circumference with a maximum height of 24 metres. The decoration project is of Lombard order, formed by a wide gallery composed of 21 arches, "very high for the diplomatic and state corps stands, the public, journalists and ladies"[1].
The schedule for the construction of the chamber was very limited. The construction was divided into two main parts, on one side the framework and on the other all the ornamental apparatus, the furniture and all the accessory works. Since the framework was the fundamental part, it was given the highest importance, also because the stability of the building depended on it. In little more than a week from the start of construction, the materials for the building were brought to the site, together with the drawings in the builder's hand.
In order to make the construction of this structure possible in such a short time, a technique of assembling the parts was used, which were specially created in various workshops in the surrounding area. Each piece was placed in the designated spot in such a way that "...the building appeared as a single unit, with no need for retouching. So that by 18 February 1861, when the King had called for the opening of the new Chambers, everything was in place"[2].

Fig. 1. Illustration relative to the session of March 14, 1861 in the First Italian Parliament. *L'Esposizione di Torino. Giornale ufficiale illustrato della Esposizione Internazionale delle industrie e del lavoro,* 15 gennaio1910, n. 1.

The chamber was inaugurated on 18 February 1861 with 443 deputies present. On the right of the throne were Umberto Prince of Piedmont and Amedeo Duke of Aosta, while on the left, in the gallery, the entire diplomatic corps (Fig. 1).
"The work, as reported in the newspapers of the time, was splendid and praised throughout Europe; it was also reproduced in numerous lithographs. It covers five years of extremely rich parliamentary activity, a crucible of the intelligence of the best men of our *Risorgimento*. The last sitting was on 28 April 1865"[3].

Working Methodology

The introduction of digital tools has made it possible to generate reality-based virtual models, which represent a complete tool for information synthesis and support in the understanding and analysis of Cultural Heritage. Through the integration of the sources, the study of the context and of the single artefact, it is possible to achieve the virtual reconstruction of 3D models of architectures that no longer exist, useful for proposing new historical-interpretative evaluations and virtual recontextualization.
The aim is to achieve a solution that is consistent not only with the data collected, but also with the iconographic and bibliographic sources and knowledge of the site [4].
In order to achieve scientific and academic rigour in projects of this type, it is essential to prepare the documentary bases in which the entire work process is collected and presented in a transparent manner: objectives, methodology, techniques, reasoning, origin and characteristics of the research sources [5].
This pipeline and the outcomes of the work presented were the subject of Michele Ambrosio's Master's Thesis (Supervisor: Roberta Spallone, co-authors: Sergio Pace, Chiara Teolato, Fabrizio Natta, Valerio Palma).

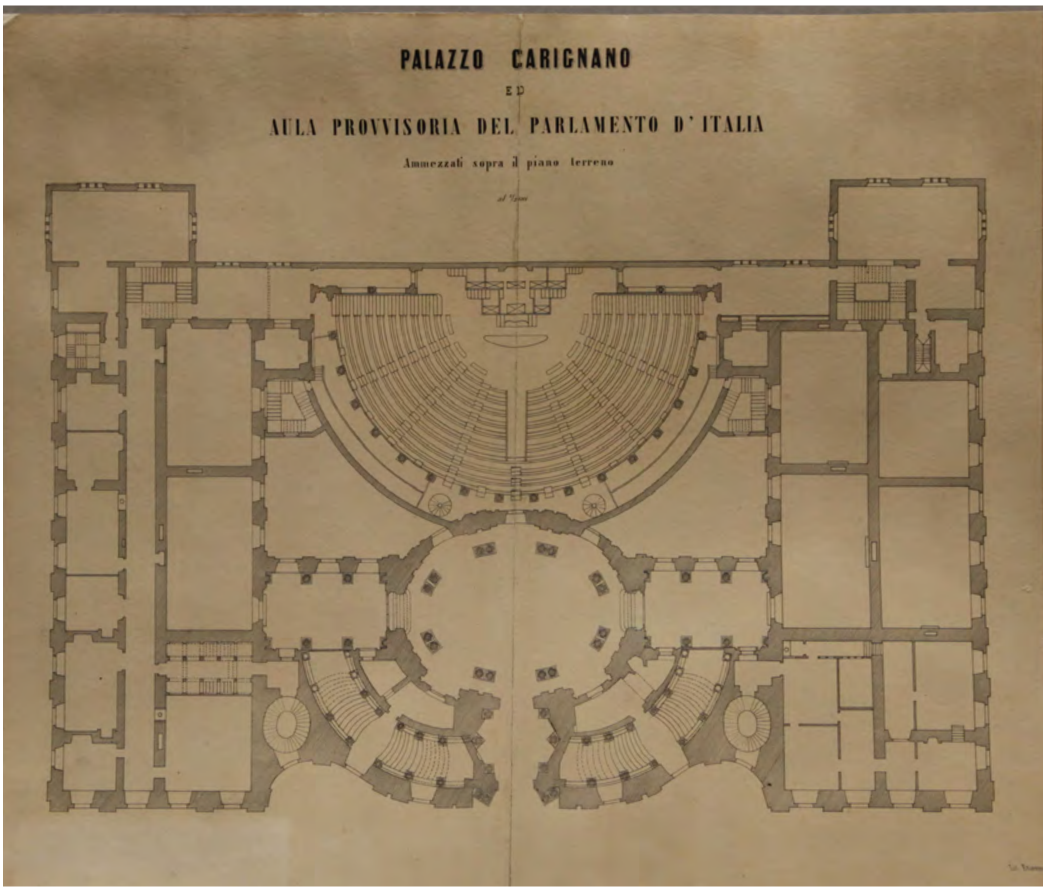

Fig. 2. Temporary chamber of the Parliament of Italy. Mezzanines above the ground floor. Risorgimento Museum.

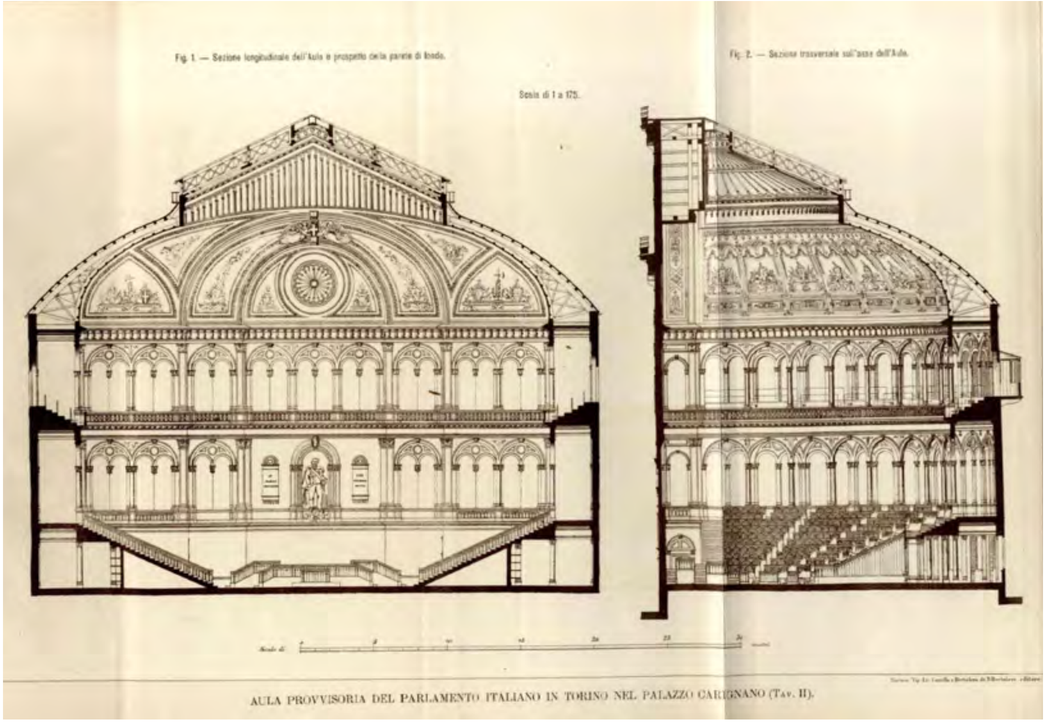

Fig. 3. Sezione longitudinale dell'Aula e prospetto della parete di fondo; Sezione trasversale sull'asse dell'Aula. In *L'ingegneria civile...* (1898), XXIC, 9.

The entire process leading to the digital reconstruction was mainly based on the definition of an objective, namely a reconstructive modelling of a building of which there is no longer any trace. The methodological procedure was developed first of all on the knowledge of the state in which the chamber was built before it was dismantled. The understanding of the structure was the action that started the process of knowledge of the work protagonist of the reconstruction activity. The process was carried out by researching archive documents relating to the building, including, in particular, an in-depth search for some of the drawings made for this project (Figs. 2-3).
Through the examination of bibliographic sources such as printed texts and newspapers of the period, it was possible to find out various information about the structure of the chamber and its decorations. Thanks to the consultation of archives and libraries in the Turin area, it was possible to go back to the iconographic and documentary sources that allowed the reconstruction of the events that took place during the construction and the period immediately following.
During the research, several views and illustrations were found that were fundamental for modelling the object of study and the main ones are presented below. The documents found in the Museo del Risorgimento were identified thanks to these sources: "A copy of Peyron's drawings for the temporary chamber was donated by the family to the local Museo del Risorgimento"[3]. "All the drawings used to make the temporary hall were requested and sent without exception to Rome, where they were normally used for the study of the temporary chamber in Montecitorio, which, in terms of shape, size and detail, reproduces those of the Turin temporary chamber"[2].
The next step was to catalogue and organise the sources in such a way that the reconstruction could be made transparent by linking the modelled elements to the documentary apparatus, which formed the basis of the research and was updated as the research process continued.
The data found was sometimes not completely consistent; the drawings in scales varying between 1:100 and 1:200 are in fact probable reproductions of the originals and published after the dismantling of the building. The integration of the missing data has been obtained through the comparison of the solutions compatible with the functionality of the parliamentary hall and the dimensional information of the architectural elements represented and/or physically surveyable.
Every source allowed the reconstructive modelling process and to make explicit an architectural and symbolic heritage of a particular historical period of our Country.

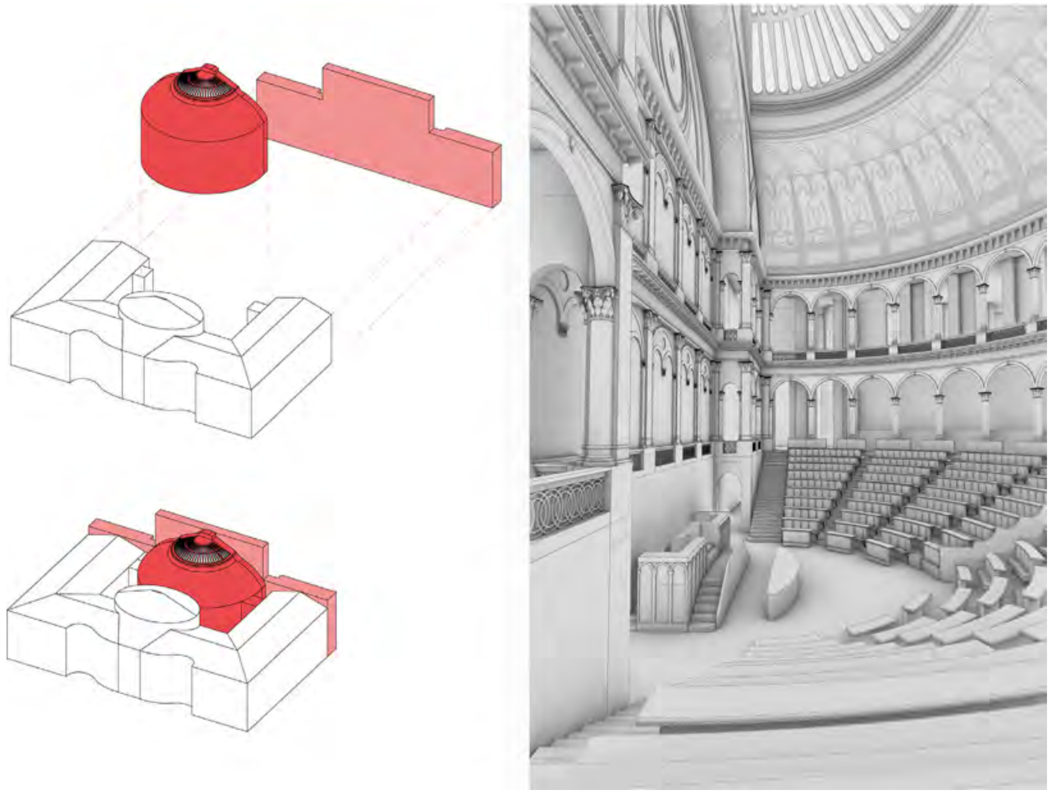

Fig. 4. On the left Schematic drawing of Peyron's work on 1860's Palazzo Carignano (Editing: M. Ambrosio); on the right Clay render of the temporary chamber (editing: M. Ambrosio).

Digital Reconstruction of the Temporary Chamber

All the sources were digitised using AutoCAD software. The redrawing process allowed for further analysis of the documents and verification of connections and inconsistencies between the various archive sources. The digital drawings produced form the basis of the three-dimensional modelling process of the work.
The modelling phase aims to generate, through the use of the software Rhinoceros, a virtual object that is the translation of the result of an investigation.
In an initial phase, a conceptual model was created, in order to concatenate the dimensions of the various elements, such as parallelepipeds with dimensions equal to what would later become a column with a capital. With regard to the decorations, reference was made to the iconographies found, although for some elements it was necessary to search for analogous elements with known and documented solutions or elements, in order to allow for their modelling (Fig. 4).
As for the coats of arms on the vault, an investigation was carried out into their origin, which led to an inspection of the still existing Subalpine Parliament where the coats of arms are still located as evidence of the destruction of the temporary chamber.
Once the modelling process had been completed, it was possible to move on to the rendering phase. The first task was to set the views and thus the relative proportions of the images to be exported. Immediately afterwards, attention was paid to the general lighting, which was configured with the model still without materials so as not to have reflections generated according to the different properties of the components.
The choice of camera positions within the Rhinoceros software was based on a careful analysis of iconographic archive documents. In fact, many of the main views have been set up by referring to drawings after the period of construction of the chamber, in order to allow a comparison with the past. The other views, on the other hand, were the result of a process that tends to enhance the main elements on which the modelling was based.
It was decided to leave almost all the renderings produced in conceptual style, except for one, which was compared with one of the iconographies. The materials were assigned in

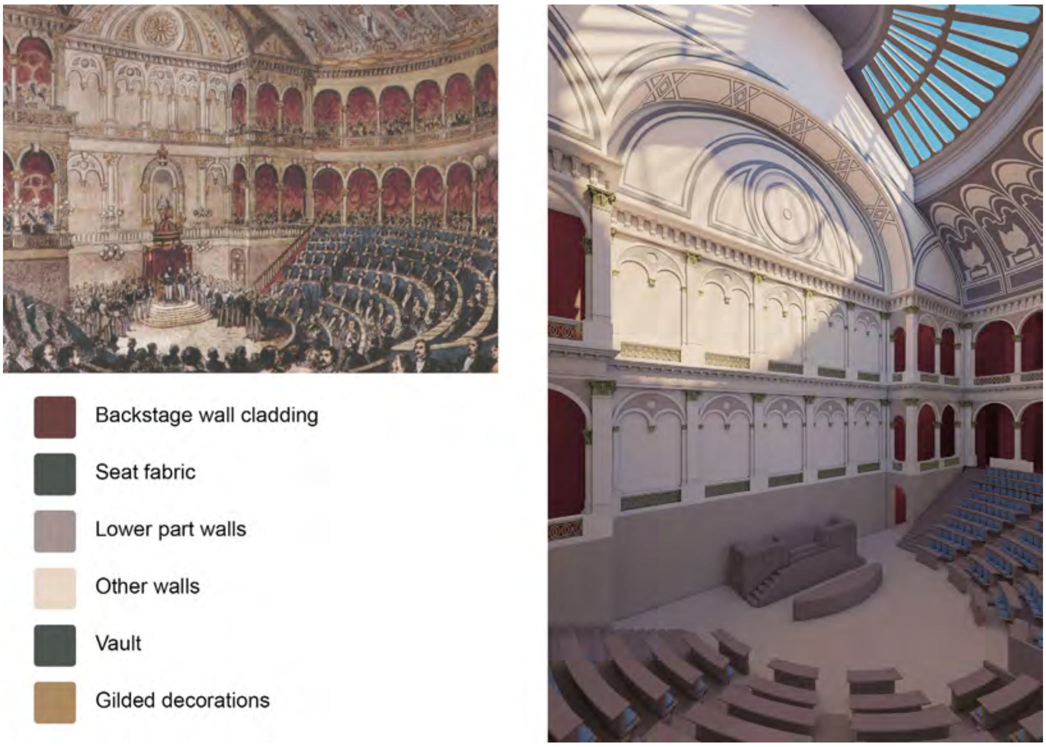

Fig. 5. On the left View of the interior of the temporary chamber during the inaugural assembly, colour lithograph based on a life drawing by Poirel; on the right Render of the temporary chamber (editing: M. Ambrosio).

the post-production phase in Adobe Photoshop. Using the eyedropper command, it was possible to create solid colour masks, which were superimposed on the conceptual render. Thanks to this procedure it was possible to reproduce what was an iconographic source, but graphically reworked through the process of three-dimensional modelling (Fig. 5).

The AR Model Application

Augmented reality requires tracking of the real environment in order to superimpose the virtual contents on the views framed by a camera. Tracking is achieved through visual techniques (based on camera images). There are two main methods: marker-based or markerless tracking.

The first adopts a camera, visualisation algorithms and easily recognisable landmarks positioned indoors or outdoors. These fiducial markers could be passive (printed markers) or, in less common cases, active (infrared emitters). The second, on the other hand, tracks the position of the camera, detecting and recognising geometric features in the real environment to establish correspondences between the coordinates of the 3D world and the 2D image. This approach can provide realistic tracking of the camera pose in real time.

In the case of the temporary chamber a passive marker approach was chosen, as the realised design is more suitable for a printed marker. The model used for the realisation of augmented reality was sectioned longitudinally. Initially, the heaviest meshes had to be greatly simplified in order to make the model as weightless as possible, allowing for a fluid visualisation. Once the cleaning procedure from Rhinoceros was completed, an export in COLLADA file (*.dae*) was carried out, which was then imported into the Blender software.

The objective was to implement a process of "texture baking", in order to create a texture that contained all the materials present in the model, as well as the lighting of the scene and therefore the existing ambient occlusion. A first difficulty was to gather all the same materials, which due to the export from Rhinoceros were differentiated for each single object present. The solution to this problem was found thanks to the use of a script created specifically to insert within each material code a node capable of displaying the UV map that would be created.

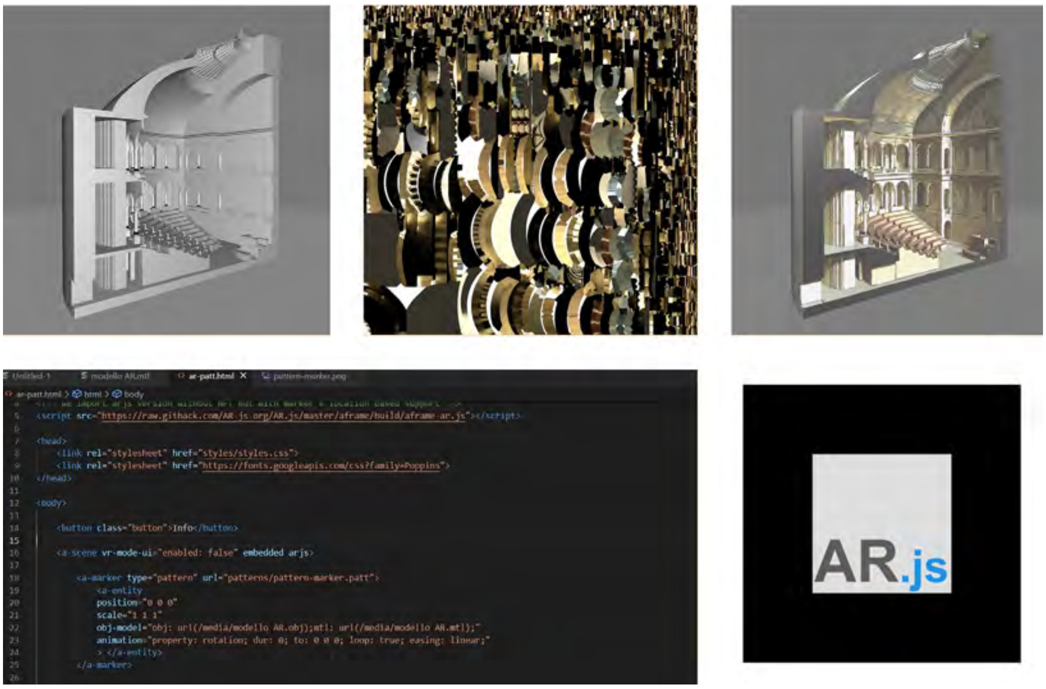

Fig. 6. On the top Texturing process for the temporary chamber sectioned model (editing: M. Ambrosio); on the bottom Project setup with Visual Studio and AR.js script (editing: M. Ambrosio).

Thanks to this process it was possible to create a unique texture.
The model was then exported in *.obj* format, which automatically generates a support file for the definition of materials (*.mtl*).
For the realisation of the AR application, the AR.js software was chosen, i.e. a library in Javascript language, which works through a web page. It is a free and open source (FOSS) project, AR.js allows AR functions to be developed with anchoring and tracking systems based on an image target.
In this case, no application was created, but the work was done on a local web page, using a target image to which the model is anchored. Visual Studio Code, a source code editor, was used to create the code in Javascript. The work was based on the import of the files obtained in the previous steps (*.obj* and *.mtl* files) and the definition of certain parameters (Fig. 6).

Conclusions

The case study, can lead to interesting developments in the filed of Culturale Heritage enhancement and immersive tourist experiences.
This study is in close relation to the cultural heritage and museum context. The working methods and objectives chosen have interfaced with the need for new forms of communication of heritage and security of personal spaces that the new global dynamics have brought.
The temporary chamber of the Italian Parliament in 1861 left a void in the courtyard of Palazzo Carignano. Unfortunately, the demolition of the chamber in 1865 left few traces of the building and thanks to the process of three-dimensional modelling, a model was drawn up to digitally represent the temporary chamber by Amedeo Peyron.
In order to make the experience complete, simplified with established pick-up and tracking points, the project can include tags with which to indicate different points of interest, specific information from the decorations and construction data of this temporary chamber inserted in a lively new digital context.
This research has been approached with the always open idea of a possible implementation, both with improvements regarding the geometries that make up the three-dimensional model, and all the representative apparatus regarding the prototyping of the visualisation of this reality (Fig. on the front page).

Attributions

This article was written by Fabrizio Natta in the sections *The Temporary Chamber of the Italian Parliament* and *Working Methodology* and by Michele Ambrosio in the sections *Digital Reconstruction of the Temporary Chamber* and *The AR Model Application*, finally sharing the *Conclusions*.

Notes

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Between Memory and Innovation: Murals in AR for Urban Requalification in Angri (SA)

Alessandra Pagliano

Abstract

The present paper reports about a recent urban acupuncture project, *Augmenting Angri*, started with its first edition in 2020 and carried on in the small city of Angri (SA). The project has adopted the city of Angri to test appropriate techniques for the enhancement of local cultural heritage, experimenting the attractiveness and easy access to digital content offered by recent augmented reality apps, with the aim of engaging the local population in.
The project therefore falls in the field of digital humanities for the enhancement of cultural heritage through ICT but, at the same time, it is also in the field of urban art, especially street art, very popular in the last two decades in Italian cities. According to a Urban acupunture approach, we combined some advanced digital representation techniques to the traditional painted street art, designing the interaction of physical murals with digital content overlapped through augmented reality.

Keywords
street art, Generale Niglio, ecomafia, urban acupuncture, cultural heritage.

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Urban Acupuncture in Angri

During the last decades, the most diffused interventions in the contemporary city are characterized by actions of recovery, redevelopment, regeneration and requalification of degraded and abandoned spaces. Bottom-up, low-cost and fast practices are spreading quite everywhere to achieve redevelopment effects very quickly, sometimes in anticipation, sometimes in compensation to the longer timelines of the traditional top-down urban planning.
We refer to urban acupuncture interventions and tactical urbanism actions, able to regenerate small public spaces, rebuilding the identity's sense in the local communities. These are two broad categories of actions characterized by different participatory practices but both able to revitalize degraded areas in the city [Lerner 2013].
Urban acupuncture recalls the Eastern therapeutic technique that, by means of punctual and targeted pressures, manages to spread the benefits to the entire city, considered holistically as an organism. The urban acupuncture uses the same methodological principles of the Eastern practice in the identification of those sensitive points capable of generating positive flows in the city. It is also characterized by local communities' participation both in the construction phases and in setting the vision for a transformation scenario that could be quickly implementable, in response to the urgent local needs. Such actions are designed to be characterized by flexibility and reversibility. Urban acupuncture "not only" transforms places by means of physical actions, but also it generates, in the local community, the ability to recognize and give value to degraded and abandoned spaces.
The present paper reports about a recent urban acupuncture project, *Augmenting Angri*, started with its first edition in 2020 and carried on in the small city of Angri (SA). The project has adopted the city of Angri to test appropriate techniques for the enhancement of local cultural heritage, through the involvement of the local population in experimenting with new forms of use based on the attractiveness and ease of access to digital content offered by recent augmented reality apps. The project therefore falls in the field of digital humanities for the enhancement of cultural heritage through ICT but, at the same time, it is also in the field of urban art, especially street art, very popular in the last two decades in Italian cities.
We experimented and tested to add advanced digital representation techniques to the traditionally painted street art, designing the interaction of physical murals with proper digital content, overlapped to the mural by means of augmented reality's app.
The leader of all these actions is the Department of Architecture of Federico II University of Naples, with the scientific responsibility of proff. Alessandra Pagliano and Paola Vitolo and the participation of students enrolled to the Master of Science in Design for the Built Environment.

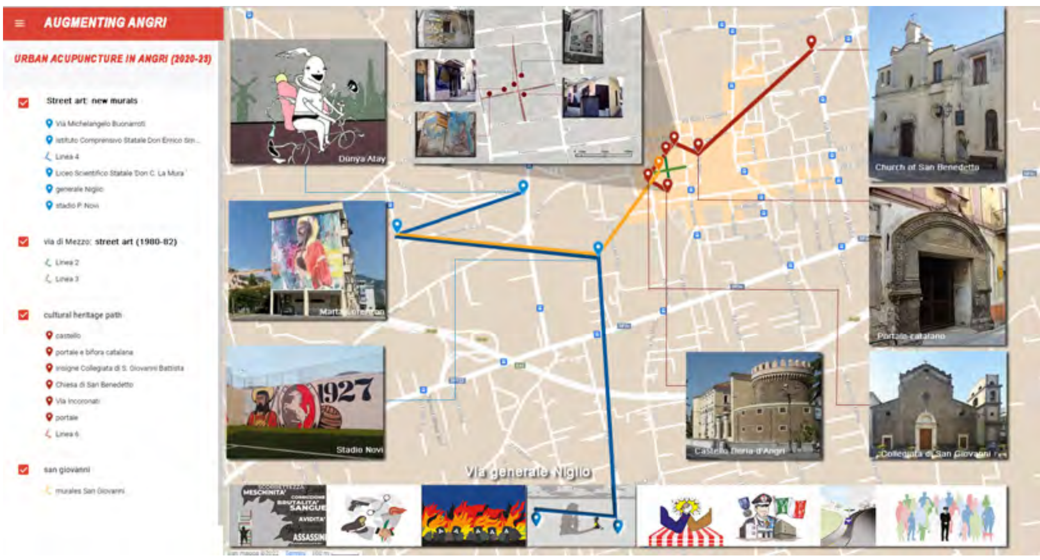

Fig. 1. Urban acupuncture map in Angri (2020-23).

Fig. 2. Square dedicated to General Gennaro Niglio: photo-installation of murals in AR.

The project is based on a careful design, at the urban scale, of medium and long term interventions, based on acupuncture techniques. The aim is to carry out high impact and low cost tactical actions in sensitive places of the city, thus creating a networks of thematic routes, intended as narrative paths connecting widespread locations.
The goal is to overcome the difficulties of the current urban fragmentation through the attractiveness of strong thematic connections, as a continuum among widespread presences. It is about linking cultural heritage assets, ancient and modern, into thematic networks, a transverse corridor between places, made of real movements together with virtual paths of knowledge.
These networks have been designed to start from the historic centre, exactly the Angevin village, then woven with other thematic routes in the neighbouring areas of the modern city; from each thematic network, we designed proper points of connection that push towards other nodes belonging to another thematic net. By connecting knowledge our aim is to produce also real physical movements in the city. The unifying element of these paths of redevelopment and enhancement ancient and recent cultural heritage, is the use of augmented reality as a communicative tool of proven attractiveness, able to trigger virtuous phenomena of involvement, in very transverse age groups, thanks to the attractiveness of digital content added to the real space. Augmenting Angri is addressed first to the local communities and customized for them.
Augmenting Angri thus becomes an infoscape project (Iaconesi, Persico 2017) for the local cultural heritage, based on the integrated use of different digital technologies, in order to promote effective forms of communication and interaction between the physical and digital worlds, in a network of cultural places and paths. Each "place" becomes a "node" of a network, made by the intersection of thematic paths drawn and aimed at redefining a new landscape, made of in situ visits and immersive experiences in digital spaces, physical relationships between places and / or connections only of a cultural nature, to generate information and knowledge. In this way, a new relationship between information technologies and the organization of the territory is structured, with the primary purpose of valorisation.

Augmenting Angri Second Edition: New Murals in AR for the Legality

The 2020 edition of the Augmenting Angri project was dedicated to preserve the memory of about twenty murals located in the historical centre by means of designing an innovative valorisation path based on storytelling, animations and digital restoration of the old murals, often damaged and sometime definitely lost [Pagliano 2020]. Since it was not possible to carry out a pictorial restoration of the remaining painted images, and since we also did not consider appropriate to remake (re-paint) those of them which completely disappeared,

the aim was to preserve the memory of that fruitful interaction, made in the early eighties, among the beauty of the murals, their social message and the urban regeneration that they activated in that concentrated urban context.
We installed an exhibition path made by small printed panels, directly affixed onto the façades and containing some markers activating augmented reality contents; in this way it was possible to bring the disappeared murals back to their original location.
All the remaining murals, in most cases only partially visible, were reproduced in their original state, also enriching each artwork with additional narrative contents. Augmented reality digital contents, superimposed to the physical reality, create a surprising relationship among three different spatial dimensions: the perspective space represented in the mural, the digital space of the augmented content and the real one of the urban environment that is physically experienced by the public. The positive acceptance of the open-air exhibition by the citizenship, which has become the guardian of the installation, still free of any vandalism, has prompted us to replicate a similar experience of urban redevelopment, through a new project of street art in AR, this time located in a peripheral area of the city, near a large parking lot frequently used by citizens and by people arriving to Angri from neighbouring areas.
Urban art is increasingly responding to the collective demand to improve the aesthetic quality of cities, as it can change the perception of a place through culture and creativity and thus promoting positive impacts on built spaces in the local community, reconfiguring the perception of spaces. Urban art can raise issues otherwise unexpressed, interpret the malaise of the local community and denounce degradation both social and physical. In the last decade, murals have transformed from spontaneous works of denunciation to art installations commissioned by the public administration. So, creativity at the service of the local community can facilitate to interpret and express the feelings of the inhabitants. In the edition of Augmenting Angri 2020, thanks to the contribution of the Embassy and Consulate of Milan of the Netherlands was painted also a new mural by the artist Dünja Atay at the outdoor spaces of the Istituto Comprensivo Statale Don Enrico Smaldone in Angri, in a popular neighbourhood near the historic centre. The augmented reality exhibition in the historic centre and the new mural by Dünya Atay (which also makes use of an expansion of the narrative content thanks to the animation of the painted shapes when framed by an appropriate augmented reality app), represent two strategic nodes through which the second thematic network of routes among contemporary street art paintings, in the suburbs close to the city centre, is put in contact with the murals in AR of the historic Angevin village. In fact, the local administration has recently commissioned Marta Lorenzon and Nicholas Perra to create a majestic mural in the Alfano district dedicated to the patron saint, St. John the Baptist, towards whom the local population feels a deep and still well-rooted devotion.
Also dedicated to San Giovanni is the recent mural painted along the perimeter wall of the Novi stadium by the artist Diego Tortora. These are authorial street art installations, commissioned by the local administration for the city, and an expression of the painter's artistic sensitivity in interpreting places and characteristics that are predominant in the local culture. In this network of recent murals in peripheral areas, the Dünya Atay's one acts as *a trait de union* between the thematic paths of the murals of Via di Mezzo and the new one under construction, thanks to the same digital technology adopted to expand the communicative potential of the works, i.e. the open source augmented reality app, adopted as an advanced representation tool and as a digital expressive medium also in the second edition of Augmenting Angri by DBE students.
The second edition theme was to give value to the toponymy of the installation site, dedicated to the Carabinieri General Gennaro Niglio. The purpose is to increase the attention of the local community towards the memory of his battles against local crime.
Here too, the project is based on the narrative capacity of the murals once augmented by digital content: citizen can establish with them an interactive relationship of fruition in support of the learning and knowledge process.
The aim of the new mural series is to underline the courage, the value and the determination of General Niglio in his fight against illegality.

Fig. 3. *Climbing the hardships:* the mural and a brief extract of AR digital contents.

With an intuitive and high-impact language that combines the pictorial expressiveness of the painted murals with the captivating expansion of its digital contents, that appear overlapped to the murals, AR integrates and expands the storytelling of each image; the goal is bringing to life the memory of a little-known local hero, to whom numerous honors have been dedicated by virtue of his constant commitment in the fight against mafias and in particular ecomafias. The motion, the diachronic development of the story, the emotional factor due to the surprise of the visual epiphany and the possibility to interact with the new digital configurations, generates a playful dimension related to the freedom of individual exploration, in a phygital reality [Zurlo et al. 2018] where the physical space is integrated and collaborates with the digital one. Each mural narrates an episode of his life, such as: the murder of Simonetta Lamberti, the awards and honors he received, the fight against ecomafias, his death and an invitation to a more active involvement of local populations in the fight against mafias of all kinds.

In order to fully enjoy the compositional and narrative aspects of the murals, it is necessary to download the free ARTIVIVE app and frame the image painted on the wall, which thus seems to come to life thanks to the animation of the static signs painted. Students have designed eight murals in a site-specific installation of the long wall between the residential area and the parking lot; the installation, strongly influenced by the pop art culture prevailing in contemporary street art, according to an appropriate sequence of murals narrates the main stages of the general's life, unfortunately totally unknown to young people, and his tireless fight against mafias. The redevelopment of the square through the positive impact of traditional street art, consisting of about 30 meters of painted wall, is enriched here with a further social value, that of the narration of an important character of recent history of Campania, whose actions are proposed by short animations that give life and movement to the painted shapes of each mural, superimposing them digital contents, specifically designed since the beginning as an integral part of the mural itself.

The static image of the mural was in fact traditionally conceived as a pictorial work in function of the artistic and visual impact on the real physical scene, in its calibrated proximity to the other murals, but the instant crystallized in those static and coloured forms is only the most significant extract of an animation that brings that frame within a flow of images sounds and narrations that expand the time of the portrayed scene and consequently the

message conveyed by the traditional mural. Augmented reality therefore provides additional perceptual and cognitive dimensions added by digital content to the perspective fixity of traditional murals: these are animations that, superimposed on the painted forms, create a narrative that expands the artistic meaning of the single work through the interface of your smart device.
Today, the capability of cultural heritage to arouse emotions, establish links and stimulate curiosity can become effective if we consider that contemporary users have completely changed: they are both 'digital immigrants' and 'digital natives' with different expectations, pre-existing knowledge, historical/cultural backgrounds and interpretative strategies.
The students of the Design for the Built Environment course were encouraged to address their project to this new audience, uncovering the evocative power of each mural to develop and enhance its storytelling. From a purely perceptual point of view, a new spatiality is created through the addition of digital content aimed at expanding and enlarging the physical dimensions of real space. These are ephemeral spatialities, illusory depths and animations, that exist only in the interaction with a smart device, which is increasingly asserting itself as our filter in perceiving the world, because capable of conditioning perceptions and actions.

Fig. 4. *Armwrestling*: the mural and some images fron digital contents in AR.

Fig. 5. *I refuse!*: the mural and some images fron digital contents in AR.

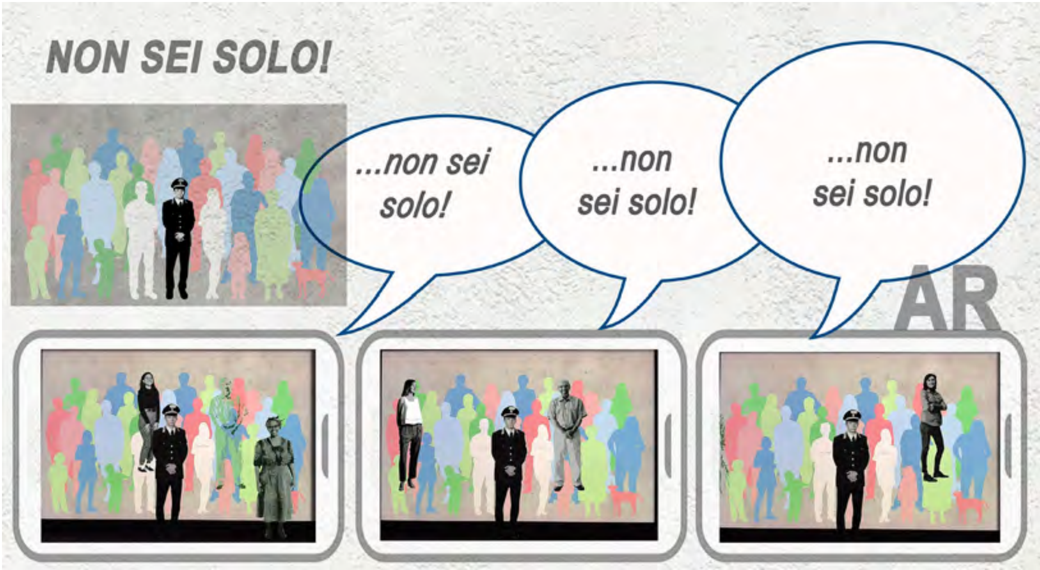

Fig. 6. *You're not alone!*: the mural and some images fron digital contents in AR.

There are eight murals and they deal with different themes, such as: the murder of Simonetta Lamberti, awards and honours, ecomafias, the mysterious car accident and an invite to social activism.
In the mural dedicated to the General's battle against ecomafias, in the augmented reality animation, the painted toxic bonfire comes to life thanks to the flames that sway in the wind, but then they gradually dies down to become a green meadow in which emerges a single flame, this time with a positive value, the symbol of the Carabinieri to indicate the General's fight against these criminal organizations. The writing "I refuse", which appears at the end of the animation, is deliberately declined in the first person, to convey to the viewer a strong message of awareness to active social participation in the fight against these criminal acts.
The mural titled "Non sei solo!" (You are not alone!) is an invitation to take active part in the fight against the organized crime. General Niglio is represented on the wall surrounded by vague coloured human silhouettes, among which the observer is invited to take his own place to be portrayed together with the general. The expansion of the narrative content of the painted static image is particularly effective here because, framing the mural, the undefined silhouettes become instead real people, of various ages and ethnicities, ready to affirm their support to Gennaro Niglio, but in general to all those heroes who are frequently left alone during their dangerous fight. All of them laudly state "You are not alone!".
With the aim of involving the local community and especially young people in the rediscovery of this fragment of recent history, and of sending an invitation to awareness and social participation, the murals, initially designed for the nearby area, will be painted in spring 2022 on the wall in front of the entrance to the high school "Don Carlo La Mura", whose manager, Prof. Filippo Toriello, has already expressed the broadest willingness of the High School to offer adequate support for logistical and organizational aspects, because the same school hosted the inaugural ceremony when the nearby street was dedicated, in 2014, to Gennaro Niglio. In the new but nearby location of the school, the installation is thus designed by young students with the active participation of even younger local students. Our project is also in line with the recent cleaning actions in some cities of Campania region aimed at removing Camorra's symbols, illegally painted in form of murals praising small and big bosses, using the strong communicative effect of street art to engage small children who can be inspired by the ideals of violence and abuse represented by these people. The inaugural event of the installation will take place in spring 2022 in the presence of local political figures and the family of General Niglio to whom the project is dedicated.
Augmenting Angri has also been selected by the Falcone Foundation, in agreement with the Ministry of Universities and Research (MUR), the Conference of Italian University Rectors of

Italian Universities (CRUI) and the National Council of University Students (CNSU), through the call for proposals "UNIVERSITY FOR LEGALITY – V EDITION", for presentation at the event of November 22, 2021 at the Aula Bunker of the "Ucciardone" Prison in Palermo in the presence of the Minister of University and Research and the President of the Falcone Foundation.

Conclusions

The aim of *Augmenting Angri* project is to test the communicative potential of augmented reality applied to different case studios, selected according to Urban acupuncture strategies in order to enhance the single cultural asset but also the whole city, intended as a live organism according to the oriental holistic approach. Augmented reality digital contents are site specific and properly adapted to the single asset. Digital contents have been designed to virtually restore lost and degraded murals, to expand the painted image adding a new spatial and narrative dimension, to disseminate Angri's cultural heritage to the same local population especially in case of frequently closed monuments than can be virtually visited, through short clip in Augmented Reality. The positive feedback of local population, especially the oldest one, is a clear testimony of the attractiveness of augmented reality and its substantial ease of use, as well as the desire of the local population to enhance their identity and cultural heritage.

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Representation Types and Visualization Modalities in Co-Design Apps

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Abstract

This paper's primary goal is to analyze representation types and visualization modalities of web-based and mobile applications for collaborative processes in urban planning. To this end, a comparative study of several case studies, based on literature review, analysis of EU projects' websites, academic/commercial websites, web-platforms, application Platforms as a Service (aPaaS), Software as a Service (SaaS) dealing with co-design for urban design and planning purposes, has been done. We analyzed 56 commercial and non-commercial apps active from 2010 to 2020 across different countries. Despite the increasing level of innovation and commercialization of Augmented/Virtual Reality solutions and immersive visualization devices in the last few years, the emerging framework of ICT solutions for participatory processes in the urban planning field is still characterized by bidimensional representations and non-immersive visualizations modalities.

Keywords
public participation, mobile app, web-platform, virtual reality, augmented reality.

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Introduction

Over the years, co-design actions within urban transformation projects progressively included digital technology tools [Steinbach et al. 2019]. Such online solutions are usually limited to a base for discussions rather than an active design tool for citizens [Mueller et al. 2018]. Currently, mobile apps in participatory processes are also not so common and mainly focus on data collection [Ertiö 2015; Guo et al. 2014]. Anyway, a wide range of digital representation tools (from 2D GIS to 3D digital twins) are available to show urban information accurately; these can interactively support the understanding of spatial features to laypeople in the urban planning field [Al-Kodmany 2002]. Virtual Reality (VR) and Augmented Reality (AR), for instance, are efficient tools to involve citizens and professionals in virtually experiencing and foreseeing the effect of a design project [Piga, Cacciamatta et al. 2021; Piga et al. 2017]. Actually, for reliably assessing the physical, perceptual, cognitive, and emotional effects of an urban transformation [Boffi, Rainisio 2017], the reliability of simulation is crucial [Sheppard 2005; Piga 2018]. This paper focuses on the representation (2D, 3D) and visualization (immersive, non-immersive) modalities applied in such tools to engage citizens.

Method

A systematic literature review using the PRISMA method [Moher et al. 2010] was conducted to investigate the state of the art of the apps' representation and visualization characteristics in the urban participatory planning field. The apps were analyzed and compared based on a matrix that identifies their different characteristics according to the following macro-categories: i) digital representation and ii) visualization (Fig. 1). The 'digital representation' category refers to how the current urban condition or design solution is depicted according to the following sub-taxonomy: a) 2D representations; b) 3D representations. The 'visualization' category indicates the way models are rendered, referring to the Milgram-Colquhoun continuum [Milgram, Colquhoun 1999]. Therefore, the visualization modes are articulated into two sub-taxonomies: a) immersive, further divided into Mixed Reality and Virtual Reality; b) non-immersive [Piga, Morello 2015].

Co-Design Apps Framework

The literature review allowed us to identify 56 apps implemented across 22 different countries, namely: Australia, Austria, Brazil, Belgium, Canada, Denmark, England, Estonia, Finland, France, Germany, Greece, Haiti, India, Italy, Mexico, Kenya, Nepal, The Netherlands, Singapore, Spain, USA. The analysis of the representation modalities highlights that 63% of the apps use two-dimensional representations, whereas 37% use three-dimensional representations (Fig. 2a) with different degrees of realism and interaction. In most cases, the apps offer exclusively one type of representation. The analysis highlights that two-dimensional representations are widely used when dealing with urban scale and are often connected to campaigns using questionnaires or to voluntary crowdsourcing contributions [Kanhere 2013]. Vector maps are a common form of 2D representation [Al-Kodmany 1999] providing the digital base maps of the current condition. Integrating these solutions into other tools, for instance, to represent design project proposals, is often possible [Douay 2014; Douay, Prévot 2015]. Three-dimensional representations are employed at the urban and building scale. Indeed, some of the apps dealing with 3D models offer the visualization of entire cities or

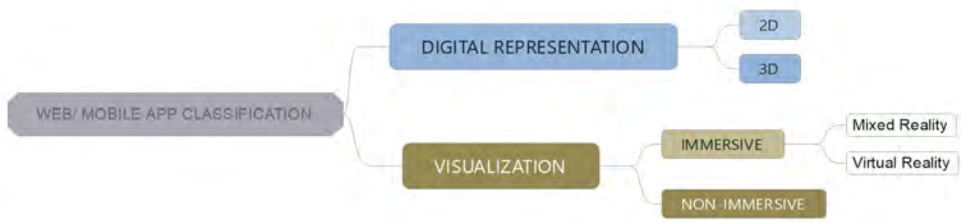

Fig. 1. Diagram of the classification modality adopted for investigating the apps.

neighborhoods, integrating information related to individual buildings, whereas others deal with architectural elements or even urban furniture, in some cases allowing the direct manipulation of the model itself. One app that adopts both representational modalities is City Sense, which uses the two-dimensional map as an orientation tool before allowing the users to interact with three-dimensional models in Augmented or Virtual Reality. Within the 3D model digital representation's subcategory, it is relevant to highlight a dichotomy: the use of 3D realistic virtual models versus abstract representation with a playful style. Despite their realistic or abstract representations, these three-dimensional models are used to display transformation projects (e.g., Virtual Singapore) or to allow final users to directly manipulate pre-established elements, or even to entirely modify the architectural model's components.
Concerning the visualization methods (Fig. 2b), 16% of the apps present the environment in an immersive way, whereas 84% use non-immersive modalities. Among immersive visualizations, Augmented Reality apps mainly show design projects in situ to verify their results at full scale and/or to record users' reactions; seldom they provide shared modeling tools in both location-based and markerless modes. Some apps of this type adopt Voxel models [Foley et al. 1996] as modeling and representational tools.

Apps Using 2D Maps

Carticipe (Debatomap in the English version) is an example of a web platform including a Public Participation Geographic Information System (PPGIS) method for collecting citizens' opinions and impressions. Users categorized their proposals in thematic headings provided by the app: i) mobility; ii) construction; iii) sports, culture, services, and commerce; iv) public spaces and green spaces; v) civic actions and the environment. Each category (Fig. 3a) is articulated in further subcategories described with a specific icon. Users can drag and drop these icons on the map to locate a proposal or a comment. Aggregated data is represented in bar-charts, heatmaps, or word clouds [1] by the app. The basic map is structured on Google Maps and allows users to switch the display between vector maps and satellite photos. A recent participatory process applying Carticipe is the "Concertation pour le Plan Local d'Urbanisme Intercommunal-Habitat", which started on July 1, 2021 and still ongoing, which involves citizens and project leaders to define the Local Housing Program (PLUi-H) considering the global warming issues and the agricultural land consumption.
Maptionnaire combines maps and questionnaires. It enables to spatialize proposals and to collect citizens' responses to specific requests. The customer defines which elements of the map the user can interact with by placing markers and drawing lines or polygons. Moreover, the system allows the customer to draw georeferenced elements; it is also possible to upload a raster image to be superimposed upon the standard map (MapBox, Bing, and Google Maps), georeferenced Geo TIFF files, or a shapefile. The questionnaire can include textual (e.g. multiple-choice, open question, semantic differential) or pictorial elements (e.g. images representing different project options). The platform also allows connecting maps with the major social networks. The system can aggregate data in heatmaps (Fig. 3b) or compare the drawings produced by the customer with feedback delivered by users on the map. An example of the application of Maptionnaire is the citizens' engagement process of the Helsinki's City Planning Department to define urban developments within a bottom-up process (2015)[2].

App Using 3D Models in Virtual Reality

Tygron (Fig. 4b) is a web app where users are involved in a game session with specific roles and budgets assigned; each role has a set of objectives to reach. The graphic style recalls the videogames graphics of the early 2000s. The user can interact with a three-dimensional model of a set of standard blocks categorized by function; in the current version, there are 17 categories (e.g. housing, agriculture, offices, parks, and medical facilities). Each category can contain various pre-set textured elements. The interactive model can switch between the current state and the design project. Environmental characteristics, such as heat or flood areas, can be represented as a color

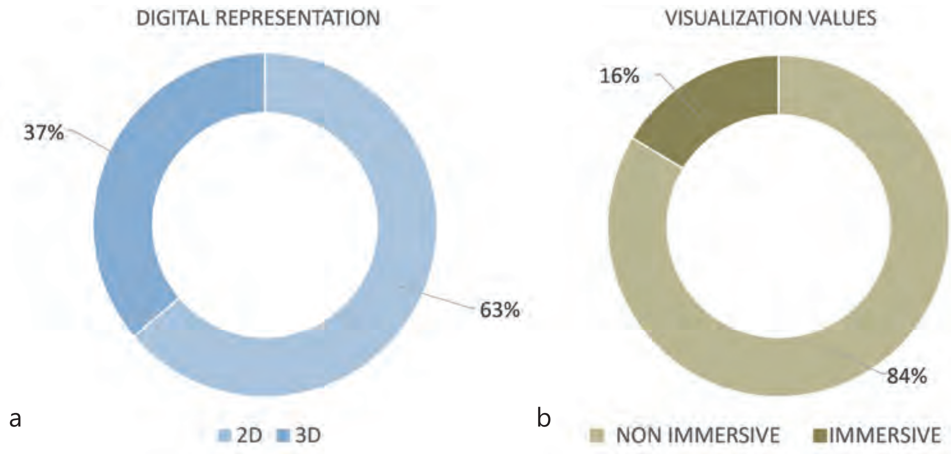

Fig. 2. a) distribution of the representation modes in the mobile and web app sample; b) distribution of the visualization modes in the mobile and web app sample.

gradient superimposed upon the model. Users' actions can influence other stakeholders' relevant objectives, and these interactions can induce shared decisions among participants. A remarkable application of Tygron was the participatory process organized by the Regional Energy Strategy North Holland South (Gooi, Vechtstreek, Netherlands) in 2019. The proposals for wind and solar plants installation[3] were shown in VR during an interactive session with stakeholders, civil servants, and council members.

The Kalasatama Digital Twins project, commissioned by the Finnish Ministry of the Environment, is an example of a multi-platform system allowing users to connect to the virtual model of the kalasatama neighbourhood (Helsinki, Finland) in multiple ways, for various purposes, and at different levels of user interaction [KIRA-digi 2019]. The Kalasatama model can display both the current state and the design projects under development in a logic of co-creation of the new city functions. In detail, the Kalasatama co-creation stages are implemented through the CityPlanner web app (Fig. 4a) developed by Agency9, [Ruohomäki et al. 2018]. Customers upload georeferenced three-dimensional models where users place their feedback using specific colors according to proposal categories (environment, residential, public works, health and safety, infrastructure, favorite place). The system can also integrate customizable questionnaires. CityPlanner itself has been developed through a co-creation process; the first application case was the "public participation GIS (PPGIS) poll" in 2015 to collect citizens' suggestions to improve tourism in Kalasatma [Charitonidou 2022; Hämäläinen 2021].

App Using 3D Models in Augmented Reality

Urban CoBuilder (Fig. 5a), developed by the Department of Architecture and Civil Engineering at Chalmers University of Technology, is a mobile app allowing a co-creation process where users can view and manipulate different design project options in AR [Imottesjo et al. 2020]. The app allows positioning standard-sized virtual blocks while viewing the project site in AR. The blocks are characterized by textures that differ according to their functions, e.g., offices, residential buildings, businesses, and green areas. Multiple users can interact with the same model, modifying the elements already positioned and adding new components. Users can have different roles (municipality, private, developer), and each role involves control over a specific budget. A cost is assigned in advance to each function, and when users locate the blocks, they view the budget used in real-time. Urban coBuilder is at a prototype development stage, a first step in testing the functionalities of the app involved architecture students in 2018; in 2022, two workshops focused on two ongoing campus development projects in Gothenburg, Sweden, by the Akademiska Hus (Gothenburg, Sweden) were done using the app [Imottesjo, Kain 2022].

Hyperform (Fig. 5b) represents an AR solution for designers and Real Estate developers' collaboration on architectural and urban projects. Created by Squant/Opera in collaboration with Bjarke Ingels Group (BIG) and UNStudio, it provides a shared immersive experience to designers and the other actors involved in the design process. The system allows uploading and displaying

Fig. 3. Carticipe a) activities pins by users; source: Debatomap (2022). https://debatomap.reperageurbain.com/ (1 March 2022); Maptionnaire; b) heatmap of users' feedback ; source: Maptionnaire (2022). https://maptionnaire.com (1 March 2022).

images, maps, data, and 3D models and manipulating these collaboratively. The app also allows displaying projects at a 1:1 scale in AR on-site to clients and stakeholders of local communities, overcoming the typical characteristic of the predetermined perspective of renderings and videos. Hand-gestures commands are used for activating a pre-established set of actions. The Hyperform app is currently used in the research and development field of BIG and UNStudio, and is not available for public use.

City Sense (Fig. 6) is an AR/VR app using experiential simulation [Piga 2017], i.e. a simulation that allows photorealistic visualizations from a subjective perspective. It can be applied on several scales, from the building to the city scale. It represents the outcome of two Horizon 2020 EIT European Project "AR4CUP: Augmented Reality for Collaborative Urban Planning" (2019 and 2020). It collects and analyzes citizens' emotional and cognitive reactions to existing urban areas or design projects before construction [Piga, Stancato, et al. 2021]. The app is based on a combined architectural and psychological approaches, the exp-EIA© (experiential-Environmental Impact Assessment) method [Piga, Boffi, et al. 2021]. By clicking on a specific area or transformation project the user enter in a subjective view mode for virtually walk through the area in VR or AR. Some questions are asked to users during the walk. The app automatically processes the collected data and produces spatialized representations of the outcomes. City Sense has been applied in different public participation processes. The first application was made in 2019 during the "Experiencing VITAE" event presenting the preliminary project 'VITAE' by Covivio, Carlo Ratti Associati and partners, winner of the

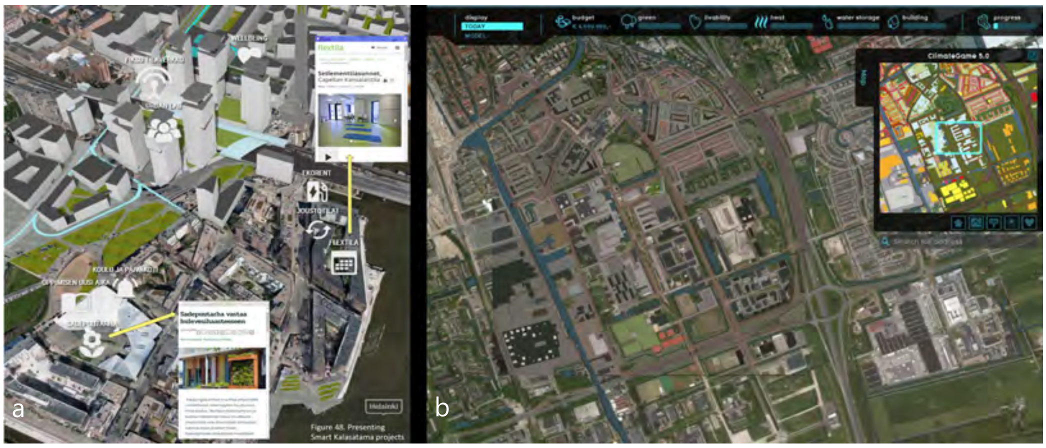

Fig. 4. CityPlanner Kalasatama a) informations on 3D model, source: [KIRA-digi, 2019]. Tygron b) main interface, source: [Koster, 2015].

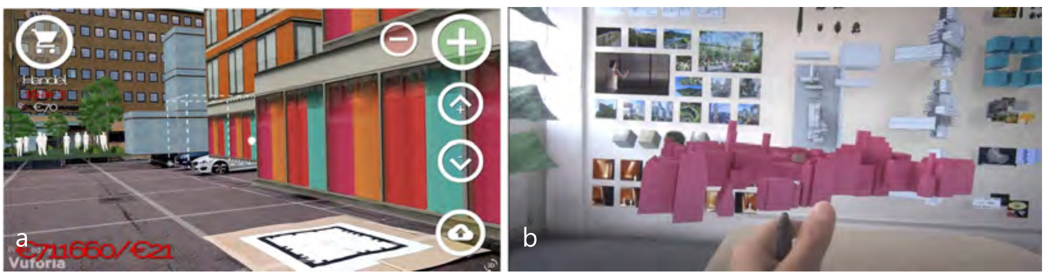

Fig. 5. Urban Cobuilder a) 3D blocks positioning in AR. Source: [Imottesjo, Kain, 2018]. Hyperform b) markerless interaction in AR, source: (Squint/Opera, 2019).

international competition Reinventing Cities (Via Serio) in Milan. Participants visualized the project on-site in AR, and their feedback, collected via City Sense and automatically analyzed, was presented to both the developer and the architects to inform the following design phases.

Discussion and Conclusions

The sample's analysis reveals that a sizeable segment of the apps in participatory urban planning uses two-dimensional representations (Fig. 2a). Textual descriptions are also widely used as a primary communication mode. These features are often intertwined by solutions allowing geo-located text; in particular, maps are often augmented with users' comments and judgments. Furthermore, some apps use geo-localized questionnaires to correlate location and responses accurately. Compared to other literature reviews on participatory apps, primarily oriented toward describing the political-administrative characteristics related to the tools [Falco, Kleinhans 2019], this paper focuses on representation and visualization features as an engagement tool for urban collaborative processes. However, whereas Virtual Reality has been experimented in co-design since the nineties [Al-Kodmany 2002; Evans-Cowley 2011], Augmented Reality has been applied more recently in participatory processes, and consequently, there is less literature on the subject [Ertiö 2015; Hanzl 2007; Thiel, Lehner 2015]. The increasing pervasiveness of high computational performance of mobile devices with immersive interaction modes suggests that an increase of Augmented Reality apps for participatory processes in urban planning will occur in the next, and maybe near, future. Although several applications are currently available for collaborative design at different spatial scales, what is not fully developed today is a single inter-scalar solution that covers all design phases at different levels of complexity. An app, recently developed and still in evolution, aiming to provide this comprehensive support is City Sense, which makes use of AR, VR, immersive and non-immersive modalities to engage citizens in multiple conditions, i.e. allowing *in-situ*, blended, or remote online interactions.

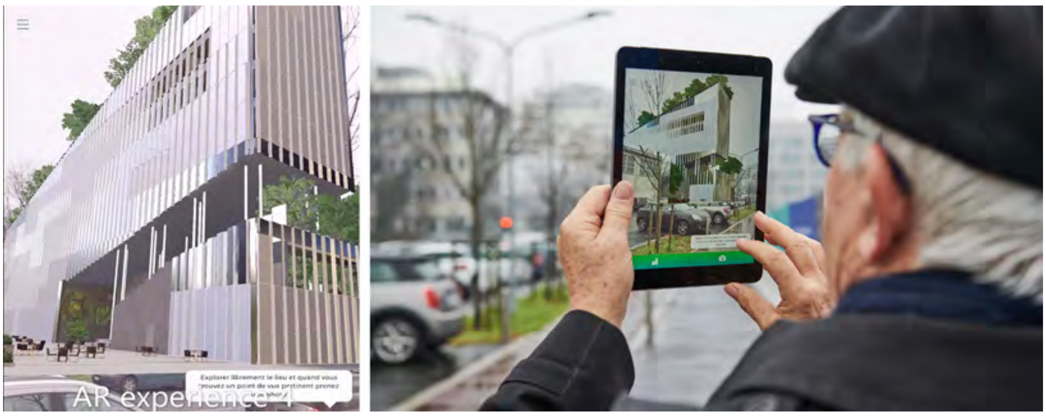

Fig. 6. City Sense: the display of the architectural model in AR mode (right); observation of the model in situ via tablet. The images were taken during "Experiencing VITAE", event held on 16/12/2019.

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Media Convergence and Museum Education in the EMODEM Project

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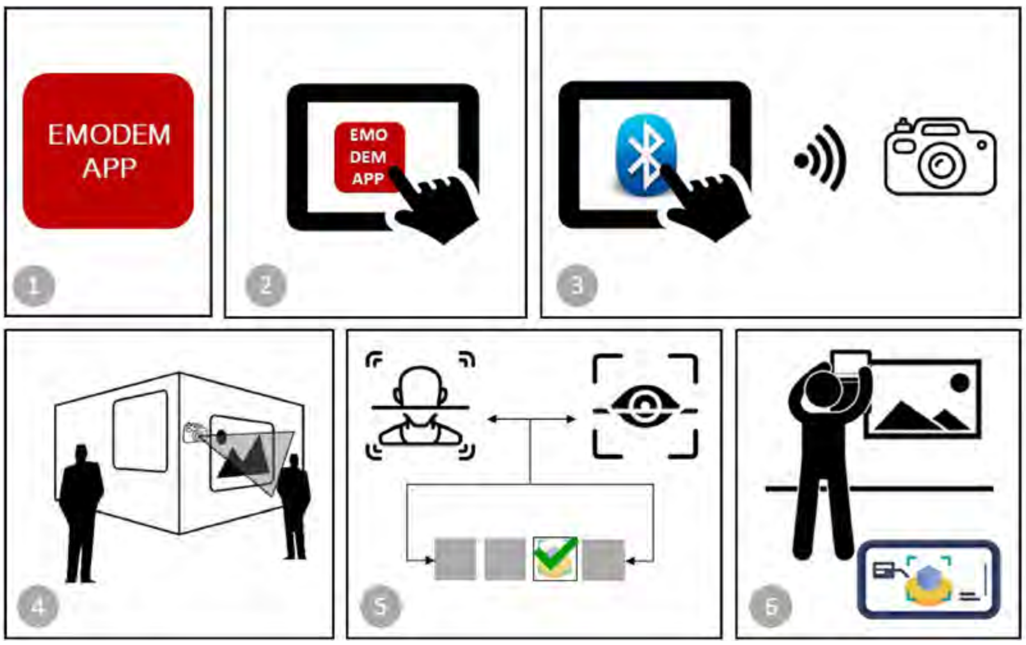
Giuseppe Nicastro

Abstract

The interpretation of the museums heritage as an active social element is the basis of the most current cultural institutions projects that envisage forms of documentation, use and dissemination of the cultural heritage increasingly dialogic (the museum community) and dynamics (mixing conversational, experiential, and participative modes).
This scenario is the broad framework of the project conceived to design the EMODEM app based on the convergence of face detection, eye tracking and AR to interface the virtual and the physical space and make the museum experience more visitor-centered, interactive and personalized.
This article integrates the EMODEM research already underway and updates the scientific roadmap according to the progress recently achieved in phases 3 and 4 of the project, presenting the technological innovation that has intervened in the meantime in the project and the advancement of research, currently reached at third field usability testing.

Keywords
museum education, machine learning, face detection, eye tracking, augmented reality.



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Introduction

Among the many areas of application of AI to the documentation, use and enhancement of cultural heritage, the main axes of intervention can be summarized in the three main directions: the digitization of collections for catalog optimization, the visitor behavior analysis for predictive purposes, the use of voice technologies as visit assistants [1].
This scenario is the framework of the EMODEM project based on the research started in 2019 on the sample case relating to the monumental complex of Badia a Passignano (Siena, Italy) and then in the Heritage Visual Storytelling Laboratory (HerViSt) transferred to the museum environment for designing an app based on the convergence of face detection, eye tracking and AR to make the museum experience more visitor-centered, interactive and personalized.
This article integrates the EMODEM research already underway [Puma, Nicastro 2021], confirming its general objectives and updates the scientific roadmap according to the progress recently achieved in phases 3 and 4 of the project, presenting the technological innovation that has intervened in the meantime in the project and the advancement of research, which roots on three main strategic axes:
– founding the cultural project on the crosscutting concept of human-centered and personalized use of digital technologies, ICT and AI, pursued through the expansion of the one-way relationship between artwork and visitor in a technologically mediated and personalized relationship between artwork, visitor and museum environment also conceived as a response to the new needs of post-covid museum management and fruition [ICOM 2020; Cicerchia et al. 2021; Charalampos 2022];
– deploying the multidisciplinary scientific set of the project, centered on the relationship between Digital Cultural Heritage and AI, in its scientific links of data documentation of existing reality (Survey), visual representation of digital contents and mixed reality experiences (Drawing) for the dissemination of knowledge [Bekele et al., 2018; Digital Day 2019; Giordano et al. 2021; SCIRES 2021];
– set up the workflow in a clearly and explicitly regulated way with regard to visitor privacy and data governance [UNESCO 2021].

State of the Art

The overarching theme of the most recent use of ICT in the field of cultural and museum communication directly concerns EMODEM with regard to three thematic and operational clusters:
1) the design of hardware and data acquisition devices in a specific environment;
2) data processing through machine learning and eye tracking processing algorithms;
3) the production of outcomes dedicated to the application in immersive AR + VR environments outputs.
Topic 1): the infrastructuring of museum environments using hardware and devices specially prepared for the acquisition of user data is dealt with in some recent experiments where the building is mainly detected and is analyzed in some flow components – such as the path accomplished, the number, gender, age class, time and distance of the people who observed each work – or to quantify and register visitors' behavior in terms of monitoring system using sensors and active cameras [Angeloni et al. 2021] – and minor residual attention is paid to the visitor's response in front of the artwork [Ferriani et al. 2021].
Topic 2): a large amount of studies and researches are published with rapidly growing literature on the whole scientific area concerning the AI system engineering, some of whose those are cited for their specific interest in key technical segments for the development of the project proposal, face detection and eye tracking.
Some of the most relevant deep learning approaches to pattern extraction and recognition in visual arts describe how the large availability of digitized painting and drawing collections provides great amounts of data for computer vision studies to be developed in tools to ana-

lyze the sensitivity to a given painting and interpret visual arts. The most impressive advances about image capturing using facial expressions allow to generate detailed visual characterization of the image, and partly to incorporate some aspects related to the observer reaction to the view, as emotions. [Mohamad Nezami et al. 2019].
By machine learning, computer sciences furthermore try to help the arts spreading improving the users 'ability to understand paintings [Lu et al. 2016; Castellano et al. 2021; Duan et al. 2021].
Other studies related to the EMODEM project focus on the eye tracking procedure conducted using the normal webcam. Although most of them are not focusing on museum environment these researches interest our project because they concern the way to process the screen calibration and how to achieve the best trade-off and how to connect questionnaires processing with automatic detection style based on eye tracking technology [Gudi et al. 2020; El Guabassi et al. 2019].
Topic 3): the vast majority of ICT outcomes production in the field of cultural heritage are dedicated to the application in AR, VR outputs and other types of digital environments with variable immersive levels [Bevilacqua et al.; Palestini et al. 2021; Vitali et al. 2021] involving the tactile, vocal, visual and sound dimensions [2].
As is well known, AR solutions allow viewing of digital contents integrated into a real scene; as is well established also in various experiences for museum use, AR allows to enrich the reading of a real scene by superimposing a digital layer capable of containing diversified multimedia outputs. AR therefore presents itself as an enhanced vision of reality and, precisely by virtue of the superimposition of virtual elements to the real world, creates an additional information layer directly connected to a specific physical element of reality. This process thus represents for users the access to critical readings and insights localized about the artwork' world, the final goal of EMODEM.

Research Objectives

Enhancing the museum' infrastructure role in educational programs was at the center of the interests of the DigitCH Group, today HerViSt LAB, already in the project "A museum in all senses", where through "talking" replicas of the archaeological finds was created an interactive educational set and in some way the EMODEM project is connected to that experience by using the currently potential of application to CH offered by Big Data analysis.
EMODEM fits into the conceptual framework constituted by the 'AI for society', which is declined in the sense of applying the feasibility of this technological innovation to improve the user experience in the museum by mixing Machine Learning applications and eye tracking with AR.
EMODEM also wants to realize the vision of the museum education framed in the Connected Learning Model, which adopts an socially embedded, interest-driven, and oriented toward educational, economic, or political opportunity approach to education.
Other recently conducted about museum infrastructuring researches have the objective of analyzing visitor' behavior by approaching the topic mainly from the point of view of the environment analysis and develop the issue by extracting data relating to the place where the work is placed. EMODEM' goal instead implements the museum proposal focusing its attention on the visitor and his spontaneous reactions to the artwork by using ML technologies to process the survey for the interpretation and the subsequent selection and proposal of contents consistent with the input received.
The EMODEM project is currently in a second stage of development, the programming of which has also been affected by the restrictions on access to museums deriving from the covid-19 prevention regulations of autumn 2021: after a first test conducted outdoors in Castelnuovo Garfagnana during the spring season 2021, some project parameters were redefined in view of a second applicative experimentation, which was possible to carry out only after several months, at the beginning of 2022, in the museum context of the Murate Art District (MAD) in Florence.

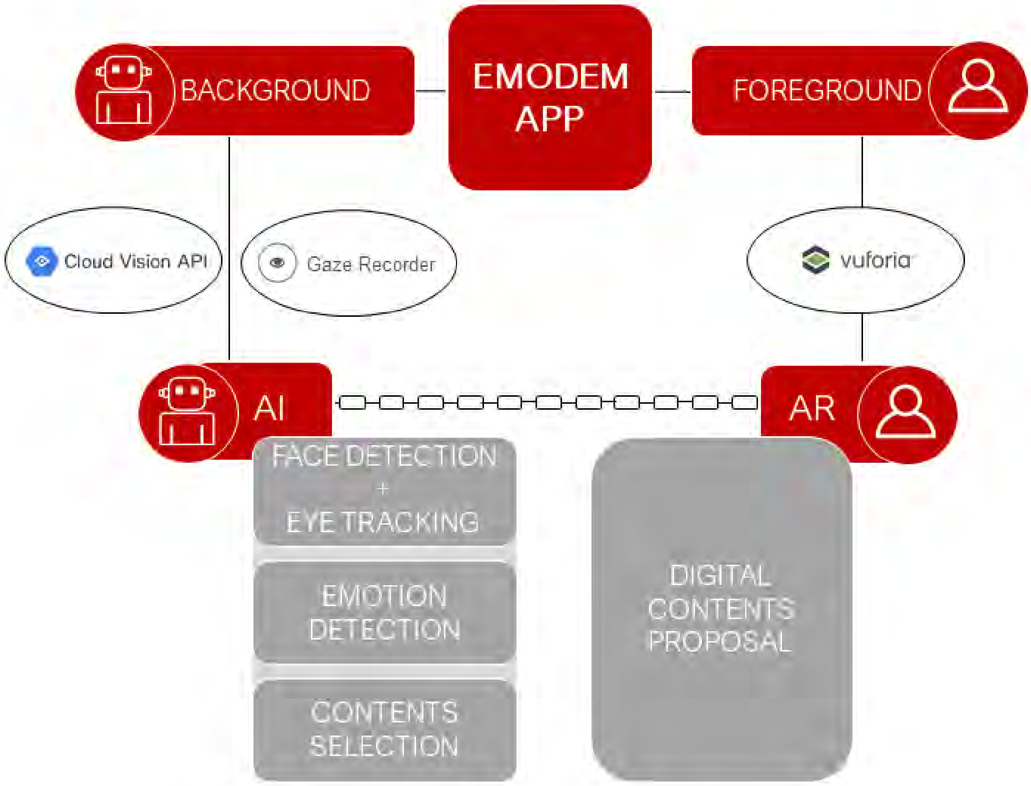

Fig. 1. EMODEM concept.

Study Design

Compared to the three thematic clusters explained in the State of the art chapter, EMODEM approaches topic 1) using low cost devices and open source sw and has its main root in topic 2), where it develops by ML the face detection segment and eye tracking to finalizing the synthesis in AR relating to topic 3 (Fig. 1).
As mentioned above, EMODEM uses image classification of the visitor' face in front of an artwork to analize and read of the reactions induced by the observation of the artwork, using a series of pre-compiled datasets that collect a large number of images relating to emotional states such as surprise, fear, joy, anger.
One of the most evident criticalities that emerged in the first research phases 1 and 2 (carried out in 2019-2020) concerned the actual possibility of the software to interpret natural facial expressions characterized by a reduced "theatricality" and, therefore, by a manifestation spontaneous.
The existing and available databases used by the working group for the alpha test in phase 1 were, in fact, populated by numerous faces images photographed in the very act of emphasizing the emotion felt: in these simulated tests, therefore, the software had been able to correctly recognize all the facial expressions proposed (precisely by virtue of the emphasis that the people photographed had placed in manifesting the different emotional states). On the contrary, the people partecipating to phase 2 test were not provided with any indication of clearly manifest the emotions aroused by the artworks and the input was to behave in a completely natural way, in the attempt to replicate the normal conditions of an artwork exhibited in a museum.
Statistical analysis of the images acquired in phase 2 under these different conditions, however, provided results that discontinuously differ from those of phase 1; taking as an example the recognition of the emotional state indicated as "joy", the overlap between the face detection and questionnaires is between 40% and 80% for 2/3 of the panel [3] and the 1/3

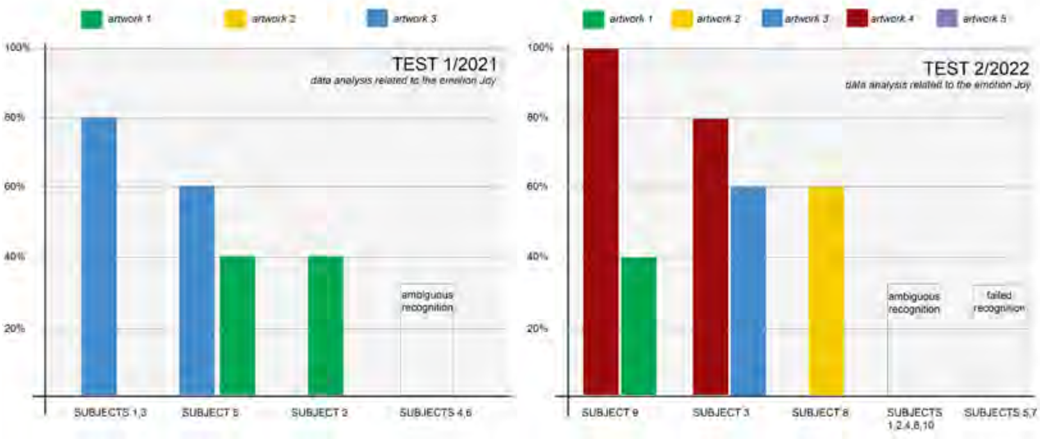

Fig. 2. Statistical analysis of the field tests.

it is cataloged by the sw with a degree of confidence too low to take these results into consideration [4] [Cohen 1988] (Fig. 2).
The results of the tests carried out in phase 2, while presenting these critical issues, nevertheless highlighted some positive aspects considered to be incentives for the continuation of the research. According to the limits of the research in progress, it is in fact necessary to point out that the face detection software used in phase 2 has a standardized training level linked to the choice of use of the open source version (Google Cloud Vision, "ready to use" version).
Despite the critical issues mentioned above, the use of a solution of this type has in any case proved effective due to its ease of use, low cost and effective recognition result of the proposed images, a condition that remains confirmed if we look at the capacity shown by the software to precisely identify common characteristics of the person photographed not directly related to the purposes of this research (sex, presence or absence of glasses, smile, etc.); therefore it is foreseeable that the future implementation of training processes specifically aimed at associating mimic characteristics and emotional states will also increase the accuracy of the application chosen in this specific task.
Based on these considerations related to the specific field of computer vision applied in EMODEM, it was hypothesized that the only information deduced from the analysis of facial expresssions needed to be integrated by other factors to be included in the input cluster taking into account other data such as body temperature, heartbeat or blood pressure (data easily acquired by sensors installed on the most popular wearable devices such as smartwatches, fit bands, etc.) or, again, data relating to the way in which people observe the images.
Based on this review, the working group therefore decided to strengthen the working methodology by integrating it with a further element of analysis including gaze detection in its workflow. The convergence between face detection, eye tracking and AR in the EMODEM workflow integrates the qualitative methodology of face detection – which detects whether the visitor is interested in the artwork – with a quantitative analysis, which detects the area of the work that the visitor is observing with greater intensity.
The integration of face detection and eye tracking technologies within the EMODEM workflow has therefore determined two distinct results: on the one hand it strengthened the methodology used, on the other hand it reconfigured the ouput-input passage of the WPs, ranging from the representation of the relevant data to the representation of the contents.
The platform for the delivery of educational contents is made up of AR solutions that can be integrated effectively in this specific phase of the EMODEM workflow, allowing to provide the vsitor with personalized information to be enjoyed directly in the vicinity of the artwork he/she is observing for enriching its reading and understanding and triggering any comparisons with further works.

Fig. 3. Project implementation.

Workplan and Research Progress

PHASE 1- task: Alpha testing has been carried out in July 2020, it consists of the selection and testing of the face detection software to be used;
PHASE 2- task: Field usability testing n. 1 has been carried out in May 2021 outdoors as it was held during the restrictions to museums access due the Covid-19 prevention. The outcome consists of the comparison between the face detection and process results of the questionnaires;
PHASE 3- task: Field usability testing n. 2 has been carried out in preparation for PHASE 4. In January 2022 a series of eye tracking surveys were carried out relating to the observation of sample images.
The measurements were conducted in a controlled environment (laboratory) and performed on a panel equivalent (in number, gender and age) to the people involved in Field usability testing n. 1.
The images proposed were also similar in number, type and exposure times. Looking at the technologies currently used in the field of oculometry, it was therefore decided to proceed using the open source "Gaze recorder" eye tracking software using the webcam integrated into a commonly used laptop.
The results related to the ocular fixation point were represented by the software in the form of specific heat maps;
PHASE 4- task: Field usability testing n. 3 has been carried out in February 2022, when it was possible to held the test indoors to verify the potential and criticality of the intermediate platform in a museum environment.
The test was conducted at the Murate Art District-MAD in Florence, a cultural district of creation and residence dedicated to contemporary artistic languages, with similar methods of data delivery and acquisition compared to those followed for field usability testing 1.
The implementation had to face a set of problems consisting of the simultaneous museum activity (visual and sound noise), the outdoor-indoor passage (adequate lighting), the disturbance of the double shooting device (face detection and eye tracking), the need to manage the attendance of participants in safety with respect to the prevention of covid-19 (shots to be carried out without a protective mask) (Fig. 3);
PHASE 5- task: lab technology validation will consist of the DBMS matching the output indications (face detection and eye tracking) with the basket of didactic contents connected to the museum heritage and the AR design of the suggested digital contents. Its implementation is in progress;
PHASE 6- task: Field usability testing n. 4 will consist of experimentation in a museum environment; it's scheduled for September 2022.

Conclusions

The increasingly broad and incisive use of digital technologies, ICTs and AI in heritage sciences promotes a profound rethinking of the notion of heritage, today increasingly understood as the pivot of society and the knowledge economy: an active social factor – of education for inclusion, relationship and promotion of the resilience of the territory – and an important resource with extensive repercussions on the value chain from an economic point of view. The most advanced museology operates in this context, where the commitment to the formation of the museum community prevails over the obsolete model of relationship between cultural institution and visitor which reduces the relationship to the impromptu presence in that single place in that specific fraction of time.
The increasingly accessible application implications of research conducted in the field of AI technologies make affordable this type of management cultural. Museum education can today even more easily use DCH to practice cultural planning that is increasingly concretely committed to outlining audience engagement and audience engagement strategies on which the museum experience is based in advanced and diversified ways.

Acknowledgments

The editorial and scientific responsibility of the chapters is recognized to: Paola Puma for Introduction, Research objectives, Study design, Conclusions; Giuseppe Nicastro for State of the art, Workplan and research progress; both the authors Paola Puma and Giuseppe Nicastro for the figure and References.

Notes

[1] See the Smart Archive Search project conducted at the Polo '900 cultural center in Turin, where smart tools are used to relate the data present in the various archives of the hub; the research conducted at the Louvre Museum aimed at analyzing the behavior of visitors regarding their stay inside the museum or their movements within the complex; the "The Voice of Art" project, in which visitors can dialogue through the use of an APP with seven works from the Pinacoteca do Estado de São Paulo, or the audio guide of the Egyptian Museum of Turin which uses the voice of a artificial intelligence to guide in the halls of the Invisible Archeology exhibition.

[2] For their area of direct reference to the topic of EMODEM we report some EU funded projects: TIME MACHINE project https://cordis.europa.eu/project/id/820323; INCEPTION project, https://cordis.europa.eu/project/id/665220; EMOTIVE project, https://cordis.europa.eu/project/id/727188; GIFT project, https://cordis.europa.eu/project/id/727040.

[3] Taking in account that a prevalent qualitative methodology was used, the number of panelist is in the usual range for this kind of test. the recruitment was carried out with incremental numbers (n. 6/10 people in phase 2/4) and, addressing the problems due the covid-19 prevention occurred all along the research, no inclusion / exclusion criteria were adopted. For the detailed description of the test delivery methods see Puma, Nicastro 2021, p. 317-318.

[4] There are cases in which both sadness and amazement have been classified as Joy. In some cases the software did not produce any valid response, returning non-qualifying results for any of the acquired images and in particular for one of the panelists the failure was total.

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Fragments of Stories and Arts: Hidden and not so Hidden Stories

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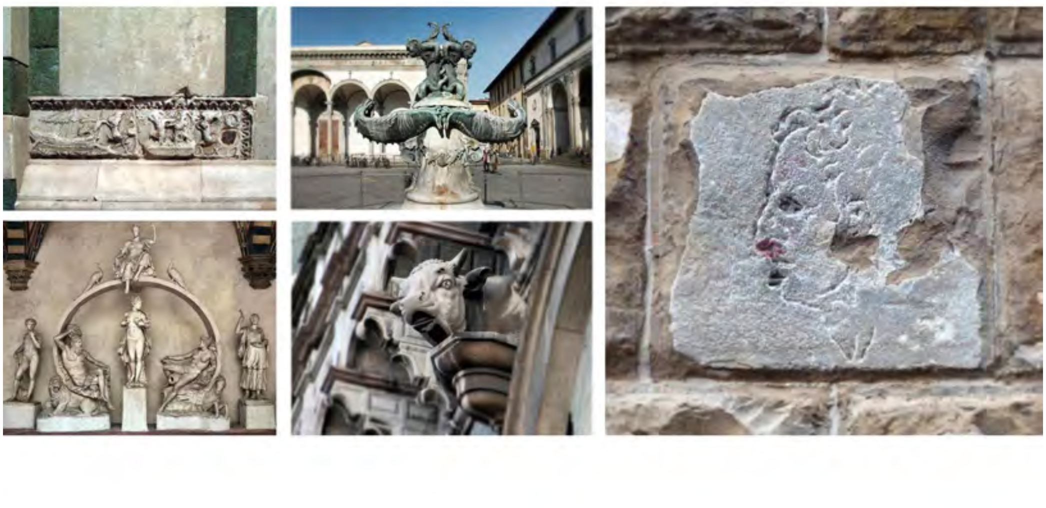
Abstract

Any city with a long and articulated past has buildings, squares and monuments linked to its history, the built heritage is its more evident direct link to the historical and artistic events that characterize the present urban asset. In between this main feature, there is the possibility that a myriad of a minor, medium or minimal sized elements may be present, creating a network of evidence, sometimes difficult to catch, but strongly connected to past events and valuable stories. It brings to light details that are often ignored or misinterpreted because of their historical peculiarities. The present research is focused on a structure based on an AR solution to make these traces in Florence downtown more accessible and discoverable. This paper base is the starting point for a special and fascinating exploration of the Florentine downtown, passing by a series of "secondary" but highly intriguing traces. In addition to the most important places and monuments, known and desired by tourists, there are details and trivia that further enhance the uniqueness of the experience in the historical and cultural city.

Keywords
augmented reality, Firenze, maps, storytelling, photogrammetry.



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Introduction – Hidden and not Hidden

In the contemporary city, the presence of the sedimentation of historical eras is present and very strong. The urban fabric that presents itself to observation is characterized by distinctive features with the presence of elements with specific relevance, mostly characterized by a high historical value, which determines the physical appearance of the Cultural Heritage connected to that contemporary society. This heritage consists mainly of architectural works and art objects that, by communicating with the place they structure, create an urban identity by interfering and integrating the city environment. The presence of this heritage connotes the place but it also receives back the influence of the place itself, which creates the complete scenography and makes the artistic / architectural work readable. So there is the definition of a system of shapes, spaces, colors, etc... that become the specific essence of the Cultural Heritage. In this, the single artwork may be the protagonist, but not the unicum, alone and isolated, to constitute the identity of the Place.
Having declared this interpretation of the Cultural Heritage, considered to be the most complete and sufficient to summarize the term Heritage, it is emphasized how necessary it is to extend the observation to two further groups of cultural-artistic emergencies affecting the Cultural Heritage: the so called "minor works" and the "histories" linked to each of them. The "small", medium or minimal artworks are distinguishable as a subset of architectural and artistic objects which present themselves with their qualities, but are not directly recognized as eminent components. When they are noticed or observed, they are recognized and distinguished for their value, but, because they are not part (by fate or past events) of the documented and promoted (and then somehow transformed into a mainstream content) Cultural Heritage, they are not part of that "Olympus" of identity presence that are subject to the tourists' massive pilgrimage.
The history of these works is distinguished by a subset of legends, curiosities, anecdotes, etc... that creates an intangible, but extremely present, environment around them. These overlays are passed on through more or less official channels, starting from more or less popular roots. They constitute an increase to the official events connected to the Architectural-Artistic object.
The history of the work is a component on which it is opportune to structure a more articulated reasoning, which is synthesized in two really relevant syntheses. The first one is the result of observations and collections, and it is the evidence that the presence of stories, legends and anecdotes is more relevant when the work belongs to the first mentioned subset. That is, when minor works are studied and investigated, it is possible to find a more rooted and varied popular tradition.
This is mainly considered a symptom of a less marked historical interest on the object, which has left its scientific documentation and sources at a more verbal level, thus opening up to a more popular and "dynamic" " treatment" of the time. To this, one can add the direct rela-

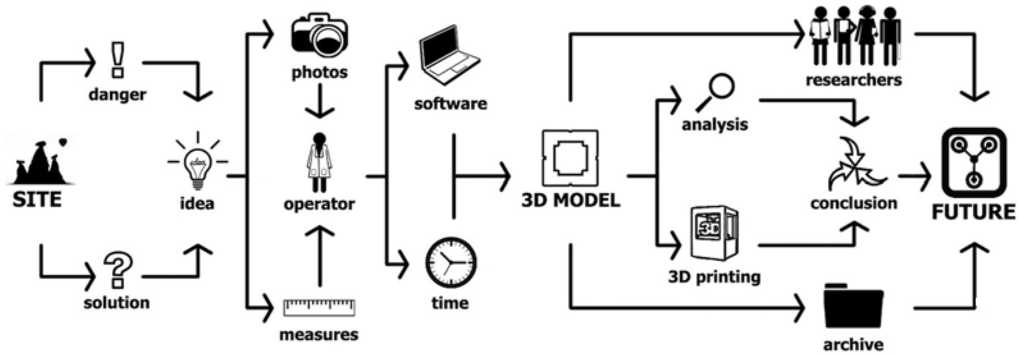

Fig. 1. Diagramming of the research process and the work plan.

Fig. 2. Pointcloud from photogrammetry in Reality Capture.

tion to the dimension of the work. Imposing and significant works, which mostly constitute the known Cultural Heritage, are realized or come to be the identity representation of the Social Place on a large scale. Urban macro-portions, if not the totality, recognize themselves in them, relating to them with a form of respect, elevating them to divinity, and receiving from above the historical narrative concerning them, handing down the key points and arriving at a historical simplification and a sifting of the contents that allows them to take root. Differently, the "minor" works take root in the urban sub-systems, becoming for those who live the places daily the identifying sign.
The works therefore become "part of the family" and their history is characterized, furnished with curiosities or peculiarities. Oddities that are most often invented or unprovable but often based on true facts lost in time.

Fragments in Florence Downtown

Any city with a long and articulated past has buildings, squares and monuments linked to its history, the built heritage is its most obvious direct link to the historical and artistic events that characterize the current urban layout and in it society finds and structures its identity. In the midst of this main feature, there is the possibility that there are a multitude of smaller, medium or minimal elements that create a network of testimonies, sometimes difficult to grasp, but strongly linked to past events and valuable stories. These elements and related stories form with the artistic-architectural component the true and complete Cultural Heritage. Bringing to light details that are often ignored, misinterpreted because of their historical peculiarities or left in the background becomes the main topic of this study. The present research focuses on a framework based on the use of AR to make these traces in the center of Florence more accessible and discoverable.
The position in the history of the city of Florence, the durability and recognizability of the Grand Duchy of Tuscany, lead to the varied and complete panorama of architectural works and artistic elements optimal for the description and development of the present virtualization project. The social characteristics frame the population as superstitious and strongly tied to traditions and historical symbols. Thus arriving at an ideal system for research.
The urban fabric presents various elements, fragments of major works or evidence of larger projects. Fragments that arrive in Florence or that take part in wider systems. Evidence of the historical and compositional complexity of architecture and art and proof of the economic, political and social dynamics that are physiologically proper to art and architecture but that often the "tourist" does not know (or forgets), stopping at the simple aspect. As said, components of historical reading that complete the work, giving it an added value that often determines a deeper character and interest. In the development of the research, the

works taken in analysis have been chosen following two main criteria: their distribution in the historical center of Florence, in order to create a uniformly diffused mesh; the morphological characteristics of the works, in order to present models differentiated by geometric and colorimetric characteristics, creating a more varied panorama of examples of the survey and photogrammetric restitution.
The subjects of the study are: the bas-relief of the Nave, decorative portion of recovery grafted in the external wall face of the Baptistery of San Giovanni; the Bull's Head, sculpture applied to the external wall of the Cathedral of Santa Maria del Fiore; the "Faccia di Uomo", engraving on a rustication of Palazzo Vecchio, also in the external wall face; the Fountain of Sala Grande (Fagiolo Dell'Arco), destined to Palazzo Vecchio and today preserved in the Bargello Museum (Faletti); the Fountain of Sea Monsters (Cresti, Ghadessi), artistic element positioned in Piazza Santissima Annunziata (Francini).

Digitization – Interaction between Disciplines of Study and Diffusion

In the field of Architectural survey, the process of integration of digital techniques and instrumentation is now consolidated. The knowledge and development of computer science has reached a high level and now allows to consider digital techniques as the main applicable solutions, thus fully overcoming the traditional method.
The field of informatics provides the world of research and communication with a new way to enable non-industry communication. The digital products of research and studies can be read and interpreted by different figures from distant fields, but who participate in common studies. Information technology and its application are today the most stable bridge for communication and exchange of information and results. Digital survey and study techniques provide speed and precision and, when carefully managed, the possibility of creating reliable and faithful archives. Parts of these qualities are applied and emphasized in this study. The rapid and precise work of the acquisition phase and the correct management in the choices of digital formats of interchange between software led to flexible and secure conclusions (Fig. 1).
The artistic and architectural objects presented in the work have been surveyed and processed with the attention of scientific research, producing useful results, archived and made available. However, the final product is an arrangement that relates to the world of tourism and education. The choices implemented in the software have been aimed at the augmented reality product, trying to guarantee quality levels useful for the final use. In conclusion, it is useful to highlight the possibility of managing a work that begins with the scientific method, produces data that can be archived and is useful, as much as it is managed in a futuristic key, and leads to elaborations that look at areas collateral to the scientific world. Therefore, creating easy-to-use and up-to-date means of dissemination that encourage the diffusion of culture and knowledge.
Therefore, the digitalization of Cultural Heritage is today the optimal strategy for the fruition of the heritage. With the survey, the object is recorded and transported into virtual space, which allows its maximum use.
Cultural Heritage is thus: available for research and study to the entire scientific community; usable for the publicizing and dissemination of knowledge at all levels of tourism; recorded in its current state for an archive that photographs our present.

Survey and Restitution – Digital Photogrammetry

The digitization of works of art and architecture is developed starting from the survey of the subject in the studio. The survey applied in the work presented here is digital photogrammetry (Pucci), an indirect survey based on the techniques of traditional photogrammetry and whose digital component is the instrument used to "record" shape and color, the SLR or MILC camera, and consequently the software used to process the data.

Fig. 3. Photogrammetry reconstruction in Reality Capture.

As the traditional photogrammetry is a technique of indirect survey, which facilitates the practice on goods of cultural significance by excluding physical contact with the object and favors the recording of the entirety of the object when it is not approachable, for safety or shape. The objects focused by the study were taken with the Fujifilm GFXN50s camera, a mirrorless digital camera with a medium format sensor (43.8x32.9 mm), producing 50 Mp images, equipped with a Fujinon 32-64 mm f4 zoom lens. The characteristics of the various shots were in line with the optimal choices for digital photogrammetry. The camera was set in semi-automatic program with aperture priority, stopping down from f5.6 to f11. Additional priority was keeping the ISO at low values, so to reduce any possible digital noise. The tripod was used only where required for low light conditions. For saving the images it was chosen the JPG format, not the optimal format for quality, because based on destructive compression, but chosen in order to contain the weight of the full dataset and to streamline the timing of the processes of calculation and restitution (Figs. 2, 3, 4).

Augmented Reality, from the Digital Model to the AR Contents

The excellent results obtained thanks to the data processing have led to the obtainment of textured 3D models, whose optimization has characterized the last phases of this research. The models obtained all have a high number of polygons that are not compatible with the use in augmented reality, not only for the difficulties that can be found within the software used for the creation of AR (Ricciardi) content but also later for its use through mobile devices.
The choice was therefore to decimate the digital models with the software Geomagic by 3DSystems (Fig. 5), setting an average of 500k polygons for each object under consideration, then concluding the process through the baking of textures with xNormal.
The model thus optimized is ready to be imported into software dedicated to the creation of content for augmented reality [1].
The creation of the first beta version of this application was carried out using a software that is easy to use and therefore also defined by the developers as user friendly, and this is the entire package of Ios developer tools, ARKit Software, within which you can find 3 software that implement each other, and that allow you to quickly create augmented digital content.
The software in question is Reality Converter, which allows you to import and apply various textures to models and export them in the .usdz format, it can also modified other basic settings such as the environment and the scale.
Subsequently the model is imported inside the Reality Composer and thanks to the support of X Code it is possible to create the interactions that the user will then have with the model and the various information and contents that with it must be disseminated. All the models have been processed and made ready for use in augmented reality, and this has made it pos-

sible to create a map of Florence (Lanier), with certain markers corresponding to the various points of interest of the secondary heritage dealt with in this paper, which by framing it with a mobile device gives access to this augmented digital content and the information it brings with it (Fig. 6).
The second phase of this research is currently underway, as the ultimate goal is to create a definitive application compatible not only with IOS devices but also with Android, and to do this it is necessary to use an additional software, namely Unity.

Augmented Reality for “Secondary Heritage”

In this case, Augmented Reality makes it possible to make more accessible and appealing a type of heritage (Pescarmona), known as secondary heritage, present in every city, which usually attracts less interest among tourists and scholars.
The possibility of sharing information about the existing architectural and cultural heritage with tools that are not innovative in their means of use but in the purpose they serve, should be considered as an option to always take into account in the field of dissemination of the heritage and education. Augmented Reality was born as a tool to expand the reality in which we find ourselves in a slightly more immediate and less articulated way than Virtual Reality, and this makes it a tool more within everyone’s reach and easier to disseminate.
The hard part is to understand what can be disseminated, what data and information to disseminate in AR so that it is clear and accessible through mobile devices, and so that the data is not misinterpreted.
It is a tool that makes content of great historical and architectural value accessible, thus enhancing the secondary cultural heritage, which is not sufficiently supported in Italy.

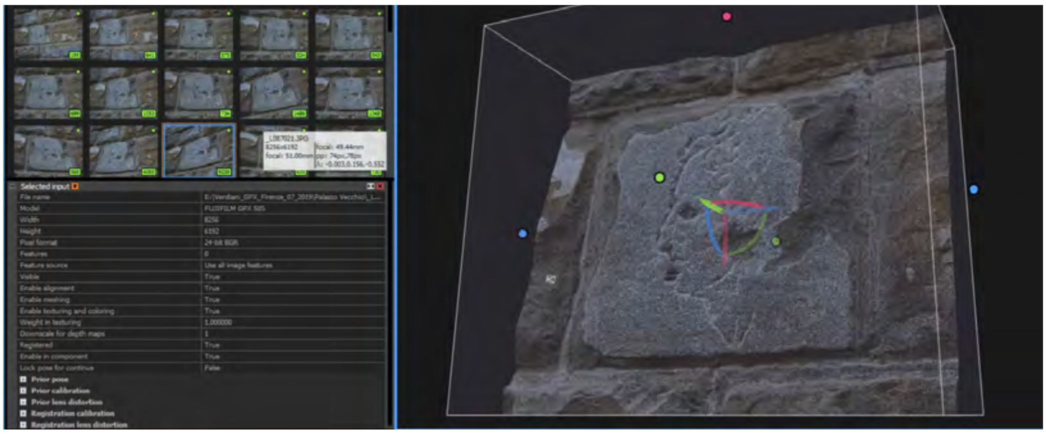

Fig. 4. Mesh 3D model from photogrammetry in Reality Capture.

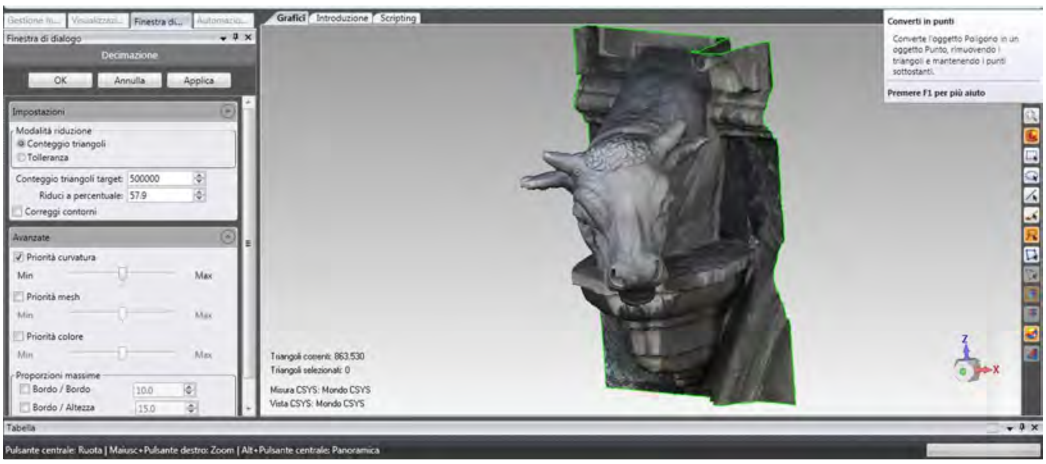

Fig. 5. Mesh model control and manage in Geomagic Studio.

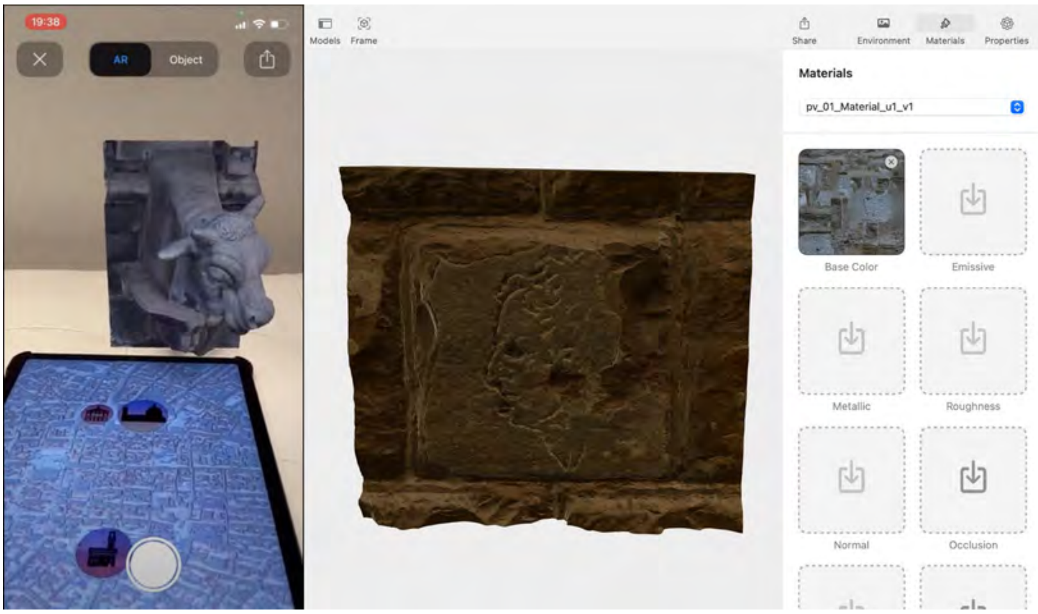

Fig. 6. IOS developer software and IPhone visualization.

Conclusions

The concept of "minor" for artworks is feeble and difficult to frame in a society more and more focused only on mainstream elements, but it represents a rich and various context that contributes to the complexity of the puzzle of components connecting the world of the arts, the town, the people living and visitng the urban area enriched by historical traditions. They represent a specific approach where the artist has operated for the benefit of the town, sharing his productions with the will to show to others an idea, an element of historical value or even moved by the intention of making a bad taste joke. Keeping these elements alive in the memory of people and promoting them as a part of a possible, alternative route, is a step towards a more sustainable approach to visiting, reconnecting the cultural environment of different periods and testifying both a continuity and a variety. The elements, in the end, need this kind of approach, to keep their role in the urban context and remaining correctly known in the mind of people, avoiding fake or superficial interpretations. This mosaic of separated artwork is not dispersive in front of the masterpieces, but may work a robust glue between places. It got all the quality and the potential fascination that may attract and justify a special visit, something that may work extremely well in combination with digital technologies, bringing them a significant contribution in terms of contents, with a worthy challange between the proper reading of the artwork, its interpretation and the choices taken to propose it to users.

Acknowlements

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Notes

[1] The 3D models of the Marine Monsters' West fountain and the Marine Monsters' East fountain are available in sketchfab.com at the URL: https://skfb.ly/oqyqv and at the URL: https://skfb.ly/oqy7

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Augmented Video-Environment for Cultural Tourism

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Vincenzo Cirillo

Abstract

In this paper a series of reflections on the topicality of smart glasses for the tourist-cultural field are illustrated. Although this technology has received a setback in the consumer market in the past, nowadays it is back in the limelight thanks to the involvement of world leaders in fashion and social networks. The objective of this paper is to show that such wearable devices can be a resource for the dissemination and enhancement of the Cultural Heritage. This assumption forms the basis of the project proposal for an 'augmented' video-environment for cultural tourism, which is presented below. It is a theoretical-experimental project and proposes an approach to the augmented reality by using geolocation technologies and 3D mapping of the territory, overcoming the simple tourist approach to Cultural Heritage, perceiving, and displaying multimedia contents that enrich the real experience of the user in the artistic sense.

Keywords
smart glasses, augmented video-environment, cultural heritage, cultural tourism, visual poetry.

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Introduction

Nowadays, there is an increasing demand for experiential facilitation of the contents of museums, art galleries and recently the historic centers of towns. In terms of study and practice to invent, design, build and/or use miniature computational and sensory devices carried by the body (wearable computing), Augmented Reality undoubtedly constitutes a potential for creating realistic learning environments [Clini et al. 2017, pp. 201-227; Trunfio et al. 2021, pp. 1-19]. As regard that, smart glasses, a technological innovation launched in the digital industry market by Google in 2013 – although they suffered a setback in the past – could still represent an interesting means of supporting for cultural tourism [tom Dieck et al. 2015, pp. 463-476]. In fact, they would make it possible to give life to real spaces by exploiting the potential of Augmented Reality, by providing, in this way, more advanced experiences and innovative contents respect to those available on smartphones, tablets and audio-guides. By means of smart glasses, the Augmented Reality would become the vehicle for substantially transforming an 'external' physical environment that includes perceptions and actions. So, the real world, ontologically inclusive, would provide a series of information that could guide actions and, at least in part, it appears as a 'processed' environment: a real space furtherly defined by the information that the prism contained therein would superimpose at the request of the user. If it is applied to the field of cultural tourism, this concept would involve an engaging experience and would make culture more accessible and desirable to the visitor, also it keeps the center of attention what really matters: the element, the exhibition or the urban space. That is possible because smart glasses, respect to virtual reality viewers, allow you to contextualize the experience during the visit in the real environment, offering the possibility of experiencing this space enriched by holograms and multimedia contents, which would allow you to narrate the events of the ancient battles by the same figurative characters or to return the deteriorated frescoes to their former glory. Some tests of application of this digital technology in the field of interest have already been conducted, for example, in the Museum of Santa Giulia in Brescia and the Villa Reale in Monza, where the smart glasses have been used by visitors to walk between the archaeological areas and move freely in the environments, by acquiring additional information relating to the historical events of the places and the characters who have lived there. Furthermore, the two exhibitions *Gladiatori* and *Assiri all'ombra del Vesuvio* of the MANN, in which the characters depicted on the *Vasus Patrocli*, animating themselves in the form of holograms, tell the origin of the fights between gladiators, going back in time to reach the ancient duels carried out in honor of the dead. It is not present only narration, but also digital reconstruction, for example of the tombstones of the Gaudo Necropolis in Paestum, carried out to explain the iconography of the finds. Through these cases, it is highlighted that the use of smart glasses would have the enormous advantage of disseminating high scientific content through language and digital representation. Furthermore, it would have offered static museums the opportunity to incorporate movement, dynamism, and interactivity. These assumptions constitute the objective of this study in which a project proposal for an 'augmented' video-environment for cultural tourism will be described, superimposing multimedia content on the architecture or surrounding context [1]. The experience, conducted in the Neapolitan territory, had as protagonists both symbolic city monuments and urban environments of considerable interest. The multimedia elements superimposed on these elements described above were the lines of some poems by the multimedia artist Anna Maria Pugliese. Through the technological application, the user can not only enjoy his experience of the place, but also understand the emotions of the artist, by seeing and reading the words among the dense nature or the cracks of an ancient building. So, it was decided to use both input and output wearable tools, smart bracelets, and glasses. As regard the use of smart glasses at the service of cultural tourism, the existing scientific literature has highlighted the action that this technology exerts on network sharing practices, opening them to the dimension of 'real time' and to a spectacular impression of immediacy. On the other hand, the opportunity of this technology as a tool capable of giving rise to specific forms of "associated" environments appears little discussed [Montani 2014, pp. 169-182].

Smart Glasses and Augmented Reality for Cultural Tourism

Since Augmented Reality (AR) is the place where the physical world and the digital contents connected to it meet, it is possible to affirm that itself AR is also the place where new meanings and perceptions are born. Thus, the physical world is enriched with digital information, such as holograms and virtual objects both 2D and 3D to which we would not have access if we only used our senses. AR spread to the commercial public in 2009, when it was launched Lyar, the first augmented reality software for smartphones. The latter together with tablets, mobile devices and webcams were the hardware initially used for AR. Sometimes bulky objects and whose use does not allow you to fully perceive an augmented world, for example by freeing your hands to interact with the surrounding environment. In 2012, to meet this need, it was decided to reproduce 3D images by using miniature projectors positioned on the frames of the glasses to which they were connected. In this way, a light, wearable, and easily manageable product was obtained, just like a classic pair of glasses (Smart Glasses), which can be defined as an extension of the smartphone within easy reach. These devices offer the opportunity to move within real environments and at the same time, through human-technology interaction, acquire more information about them without taking your eyes off what you are observing. Strictly speaking, the product conceived by Google X Lab, that were strongly desired by the creator and founder of Google, initially aroused a lot of fervor and an anxious wait which ended in 2013 with the launch of Google Glass at the developers and in 2014 on the market commercial. The first problems immediately arose related to both the protection of privacy and the excessive cost of sale, two mountains that seemed insurmountable and that decreed the end of the spread of Google Glass as a consumer product at the beginning of 2016. Since then, the company designated this product exclusively to the professional and corporate field with the production of the Google Glass Enterprise Edition, but in recent years a strong interest in smart glasses has spread again both from leading companies in technological production and from high fashion brands, passing through the creators of social networks. An example is even by the Ray-Ban Stories which are defined as the first Facebook smart glasses. The devices were officially presented on September the 10th, 2021 and have sanctioned the multi-year collaboration between Facebook and Luxottica. According to most people, they represent the first step towards the spread of the metaverse and they are a springboard although far from the idea of smart glasses with integrated augmented technology through which to see additional information and 3D digital objects appear in real space. In fact, it is well known that Facebook's Reality Labs (world-class team of researchers, developers and engineers who develop projects for connecting within augmented and virtual reality) have been working for some time on smart glasses for AR through the *Project Aria*, for which it is still estimated a work of 5-10 years for the public market. Furthermore, the release of Facebook's so-called smart glasses has resulted in an acceleration of the production of similar hardware in competing companies. A few days after the presentation of the Ray-Ban Stories, Xiaomi also launched its smart glasses on the market. Respect to Facebook glasses, they focus everything on augmented reality by allowing information to be superimposed on the user's field of vision, for example showing notifications, messages, driving directions, reviews, etc. Xiaomi is not the only company to work on this field: other companies such as Google, Microsoft, Apple, and Epson are working in this direction, too.

Although the future development of this technology is not yet well known, recent studies that were conducted in the field of cultural heritage [Bonacini 2014, pp. 89-121; Cennamo 2021, pp. 123-127] show that smart glasses represent an interesting means of supporting of cultural tourism, highlighting how they represent an ad hoc innovation to respond to the request for experiential facilitation of the contents of museum collections, art galleries and town visits [Brusaporci, Maiezza 2021, pp. 2044-2053]. In these searches, as well as in the international Google Glass Museum Zoom experience at Manchester Art Gallery or in our local OK Venice! the visitors experienced museum collections and urban environments without any obstacle in their hands and seeing to appear in their visual field multimedia informations pertinent to what they were observing. In this way, awareness of the historical and cultural heritage increases by making it easier for those who are not experts in the sector to understand it [Kalay et al. 2007; Voinea et al. 2018, pp. 93-106].

'Augmented' Video-Environment for Cultural Tourism in Naples

The use of devices equipped with image acquisition and projection technology allows to accompany an experience lived off a screen through a graphic interface. The latter allows to code the result of previous experiences, to translate them into contextual graphic suggestions and to the user of the AR (Augmented Reality) display device to benefit of "binaries", that is signals capable of directing attention to an order of operations given by the priority of their performance.
The problem of defining digital objects and their spatial relationships in a scene requires a pool of multidisciplinary skills which encompasses themes such as physics of light, computer vision, artificial intelligence, and object-oriented modeling. In this case, with regard to the production of content (in particular Kinetic Typography located in places of cultural interest), the augmented reality experience, which allows the user a complete immersion in the artistic space, requires: mapping of the selected site; appropriate digitizations; modeling of kinetic geometries and their animations; real-time analysis of light conditions; triggering of virtual props based on the user's dynamic position. This type of work involves preliminary data collection operations on the site and adequate mapping and digitization of it, even in a pre-design phase with respect to the contents. In this regard, current digital technologies present themselves as a convenient solution for various reasons, including the possibility of carrying out multiple use tests in a simulated environment that exploits the rendering capacity to display the content in its fruition form while it is being used prototyped.
In fact, the best option to carry out research and development is to simulate the test environment with a model that is sufficiently realistic to be able some form of evaluation.
In this direction, the project presented here in a theoretical-experimental way and in the field of videoart, proposes an approach to augmented reality by using geolocation technologies and 3D mapping of the territory. The 3D contents interact with the three-dimensional part of the territory since they provided feedback in the real part which can be viewed by the user. This basic concept would allow third-party developers to create contents and applications in various fields such as social networks, directions, reviews, artistic applications.
The technologies identified for the activation of the process are (Fig. 1):
– a reference device for data storage (smartphone or tablet) equipped with a processor capable of processing a 3D;
– an input tool that allows to control the interface without using a smartphone (it can be a band sensor, a bracelet or a microphone for voice inputs);
– an output tool (necessarily a pair of glasses with a technology capable of projecting the interface from which content and applications can be accessed on the retina);
– a software that manages, together with the smartphone operating system, the 3D interface and the superimposition of the two realities.

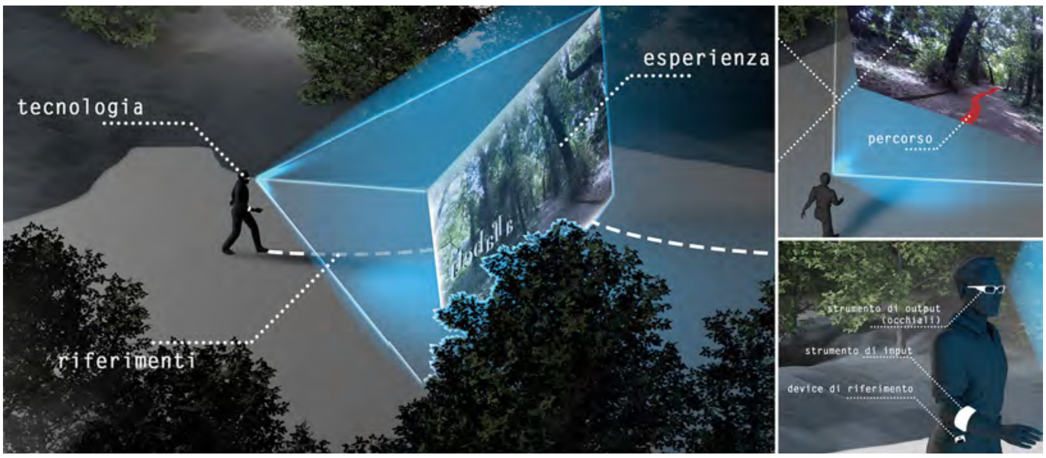

Fig. 1. Theoretical representation. Augmented video-environment: analysis of the necessary elements and technologies (by Gabriele Del Vecchio).

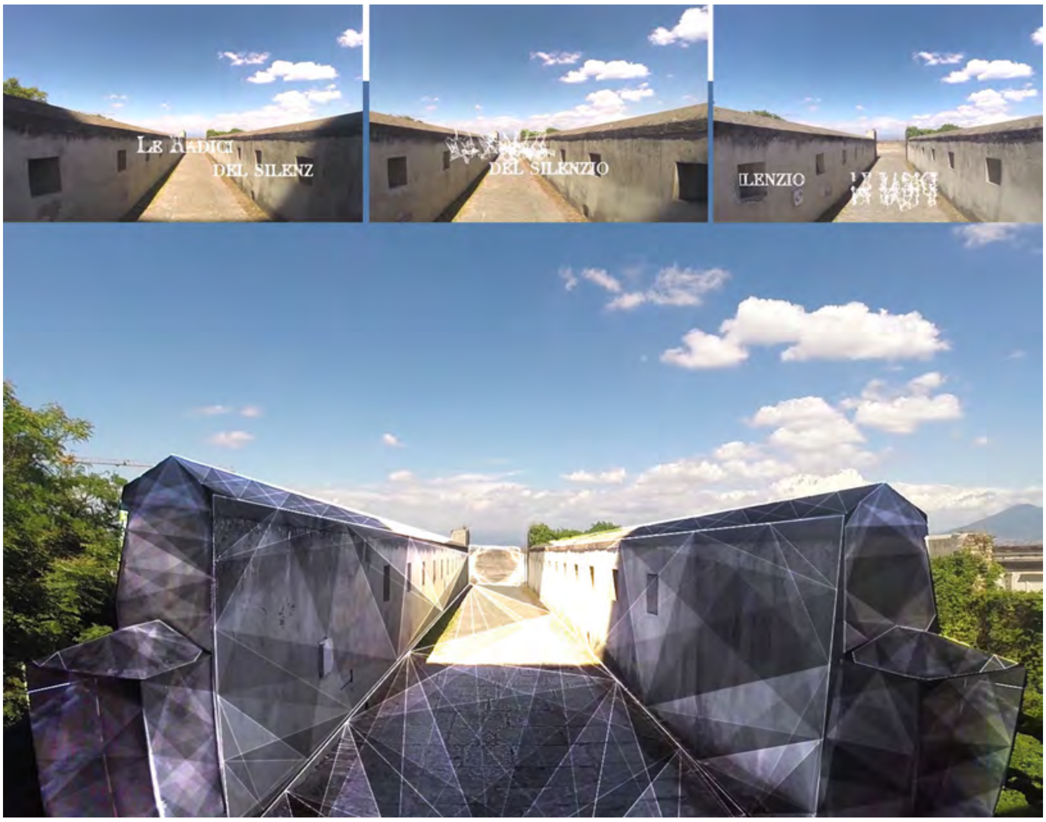

Fig. 2. Theoretical representation. Augmented video-environment for Castel Sant'Elmo in Naples (by Gabriele Del Vecchio).

Furthermore, support and an active community of users and developers is considered necessary in order to have more content to insert and more applications to develop.
These experiences are set in some Neapolitan places that are characterized by a strong historical, architectural, and environmental connotation, such as the Real Bosco di Capodimonte, Forte Sant'Elmo and Piazza del Gesù Nuovo. In them, while the user walks in the real environments, the verses of some poems by Anna Maria Pugliese appear among the branches of the trees, along a bastion of the fort and around the spire of Immacolata Concezione dissolving thanks to a sound spatialization designed in rhythm with the visual contents of the media experience [Zerlenga 2020, pp. 124-127]. The latter is made up of whispers or light musical accompaniments, in rhythm with the visual contents, without however excluding what is the context in which one person finds himself. In a specific way, the individual experiences were simulated by shooting video with a high-resolution camera and using a fish-eye effect in video editing to reproduce the vision of the human eye.
On the top of the Vomero's hill stands the majestic fortress of Castel Sant'Elmo, a mighty building, partly obtained from the living rock, which originates from a Norman observation tower called Belforte. Due to its strategic position, the castle has always been a coveted possession from which to have complete control of the city. For such an evocative place of history and collective identity it was decided to associate the poem *The Roots of Silence*. By using Kinetic Typography, the poetic lines slide towards the observer, dancing and dissolving as he advances with effects that respond to the essence of the words themselves; for example, the word 'nomad' escapes from one side of the screen to the other or 'silence' enters like all other words and then becomes silent, and it is reduced to a series of points until it dissolves. In order to obtain these solutions, there was a need to superimpose a three-dimensional model on the actual physical consistency, thus letting the words interact with the surrounding environment. A wireframe effect was used as an application that breaks down and reassembles in a different way depending on the meaning of the word (Fig. 2).
The poem *The Alphabet of Trees* has been associated with the Real Bosco di Capodimonte, a park full of nature in the palace of the same name that covers about 134 hectares. In this

Fig. 3. Theoretical representation. Augmented video-environment for the Bosco di Capodimonte in Naples (by Gabriele Del Vecchio).

application, poetry "grows" with nature, appears, and dissolves, following the path of the observer and becoming one with nature. It was necessary, compared to the previous case, to perform a geolocation of the coordinates to obtain a correct insertion of the words in the natural environment (Fig. 3).
The last application was carried out in the heart of ancient Naples, along the path of the Greek and Roman roads, involving the majestic spire dedicated to the Immaculate Virgin. Its thirty meters high together with the marble decorations, make it the tallest and richest spire in Naples. Also, in this case the prose verses appear to enrich the real environment, placing themselves in concentric circles around the spire and wrapping it in full respect of its morphology and following its profile (open figure).
The proposed experiences are the result of a composition of elements where, for them to interact with each other and with the surrounding space, the program must interface with the environmental 3D model superimposed on the real one, since it is necessary to scan it. The path to be followed will be understood from the experience of the content entered and no default symbol or map will be prepared. Furthermore, moving away from it, the program goes to stand-by and, if the content has not yet been sent out, notifications will help the reconfiguration and recovery of the path. In addition, there will also be a way in which the contents will be placed on the 3D scan carried out by the user in that moment, making the experience unique as it is generated by the user himself.

Conclusions

The enhancement and dissemination of Cultural Heritage, as well as the accessibility and use of cultural sites, are increasingly entering the digital sphere. In the same way, albeit not with the same speed, in the technological field people are increasingly aiming to develop software and hardware that allow the digitalization and continuous connection of the physical world, thus making great strides towards a world in which digital will overlap in all fields to physical reality. This is also demonstrated by the fact that, as previously illustrated, the world's leading production giants are all betting on augmented reality wearable devices. This translates into new and important possibilities in the field of cultural tourism. Smart glasses represent an op-

portunity for visitors to make exciting and highly cultural and educational experiences, knowing not only what it would be possible to learn from reading traditional information installations, but also the incessant and copious research work behind a restored work or historical attribution. Furthermore, by these must accommodate many users, aspects such as practicality, the ease with which it is possible to wear them, the ability to customize or disable the controller keys or that, through the advanced features, should not be underestimated, to enable the automatic display of content in Augmented Reality, without any input from visitors: all while having your hands free. Fundamental features for a device that can be used by the most expert people to beginner ones, thus obtaining a cultural, virtual, multimedia, multisensory experience and without having to delete the real images of the path that is taking place but superimposing digital content on it. However, it must be considered that, despite the widespread use of digital devices, people are still not used to wearing smart devices and this aspect could be a reason for failure. The CEO of Facebook understood this well and, asking the important fashion brand Ray-Ban for help for his glasses, showed that he wanted to proceed in stages, first getting people used to these new accessories and then gradually introducing new one's functionality little by little that technology is miniaturized. This would allow you not to stumble upon a bankruptcy experience like those of companies that have previously tried to make similar products, for example, Google, Bose, and Snapchat. The other reason that could lead to the failure of this initiative is the very discussed issue of privacy, probably one of the reasons for the initial disappearance of this technology from the consumer market. Since the very beginning, apps that make use of facial recognition and video and photo recording have been of particular concern. To overcome this problem, manufacturers are developing aesthetic designs of the devices that show when these actions are in progress and are arranging for the use of clear voice commands needed to activate them, to make people feel nearby what is happening.
Use and involvement seem to be the key words for the use of this technology in the field of interest. To achieve this, it is desirable that, as in the field of corporate production in which smart glasses have spread and are expanding for years, customized functions are optimized based on specific and previous needs. In this way, touch or voice commands and the same morphology of the glasses can be performed and customized according to the scope of application: indoor or outdoor environments for tourism.
Only in this way can augmented reality for visitors to art galleries, museums, exhibitions, and towns will be a valid support to their imagination, for example to have a possibility to understand how an extinct animal walked, what was the original appearance of a mutilated work or the original configuration of a building. Furthermore, it could represent how to make a further enrichment of the Cultural Heritage through artistic applications.
In this regard, the project presented overcomes the simple tourist approach to environmental assets, perceiving and displaying multimedia contents that enrich the real experience of the user in an artistic sense by superimposing on physical reality (places, monuments) virtual contents [Cirillo 2020, pp. 169-170]. So, the user will be able to live simultaneously experience of the place and the artistic context designed therein.

Notes

[1] This contribution is the result of a multidisciplinary team. The chapter *Introduction* was written by Ornella Zerlenga; the chapter *Smart Glasses and Augmented Reality for cultural tourism* by Rosina Iaderosa; the chapter *'Augmented' video-environment for cultural tourism in Naples* by Marco Cataffo and Gabriele Del Vecchio; the chapter *Conclusion* by Vincenzo Cirillo.

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AR&AI classification and 3D analysis

Supervised Classification Approach for the Estimation of Degradation

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Abstract

The study presents an innovative approach to classify geomaterials using supervised classification methods from orthophotos derived from UAV (Unmanned Aerial Vehicle) and photogrammetric processing. The case study examined is the *Ponte Rotto*, dating back to 20 BC, which in antiquity allowed the Appian Way to cross the Calore River – between the provinces of Avellino and Benevento – to continue towards the port of Brindisi. In previous studies, experts on geomaterial diagnosis estimated – from aerophotogrammetric orthophotos generated for both bridge elevations – the geomaterials and quantities used for the construction of the monument and an overview of the state of conservation of the monument studied. Orthophotos of facades were imported into CAD software and used as the basis for – according to a manual process – the mapping of the materials. The work presents the results according to automatic Machine Learning clustering from the same orthophotos to identify geomaterials.

Keywords
UAV, photogrammetry, semantic image segmentation, geomaterial distribution.

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Introduction

The generation of digital models and outputs for cultural heritage, in the form of point clouds or 2D products, is a powerful tool for scholars, architects, archaeologists and curators to support analysis and planning operations. Therefore, the correct management of these resources is crucial for better understanding the investigated asset and developing appropriate conservation strategies [Álvarez 2021]. Many of these procedures in professional practice are still linked to conventional techniques, such as manual drawing using CAD software. For example, the survey for restoration is characterised by a considerable attention to the reading of the state of conservation, to the stratification of the masonry and to the crack drawing. These representations are made by manual work guided by specialised operators who often rely on in situ analysis and their personal skills.
In parallel to the traditional approach, the analysis and automatic extrapolation of information from digital models is undergoing rapid diffusion, with significant advances in the procedures for segmentation and classification of 3D models or 2D drawings. As known segmentation is the process of grouping data into homogeneous clusters with similar properties, while classification is the operation that labels these clusters [Grilli 2017]. In the literature, we can encounter many studies on the topic, mainly driven by specific needs provided by the field of application (building modelling, heritage documentation and conservation, etc.). Most segmentation algorithms are tailored to work with a 2.5D surface model hypothesis coming, for instance, from a LiDAR-based survey. Many algorithms require fine-tuning of different parameters depending on the nature of the data and applications. Most of these are supervised methods, where a training phase is mandatory and crucial to guide the subsequent machine learning classification solution [Guo 2015; Niemeyer 2014; Xu 2014; Weinmann 2015; Hackel 2016; Qi 2016]. Considering the availability and reliability of segmentation methods applied to imagery and the effectiveness of machine learning strategies, we present our work and methodology developed to assist heritage workers in analyzing artefacts, the core of which consists of 2D segmentation of orthophotos derived from photogrammetric survey for geo-material classification.
The benchmark for the proposed methodology is represented by the *Ponte Rotto* (Broken Bridge). The structures still preserved today can be traced back to a viaduct built with quadrangular pillars in opus quadratum, arches, and gable end walls in concrete covered with bricks. Unfortunately, only the western ramp on the left side of the river Calore, made of bricks and limestone blocks, and three pillars on the opposite bank and an arch are preserved today. These structures have already been the subject of a study that, starting from orthophotos derived from photogrammetric survey, has returned, among other outputs, a lithological map showing the percentages of the different materials making up the artefact [Germinario 2020]. The whole procedure was developed with a traditional approach, reworking the orthophotos in a CAD environment and drawing the boundaries of the different regions. Our research aims to propose a machine learning technique for the localization of the different geo-materials that allows an efficient classification with a reduction of manual input. The segmentation results are then compared with those obtained from the traditional approach, to highlight possible deviations in the percentages. Such operations can facilitate the study of heritage monuments and integrate heterogeneous information and attributes, useful to characterise and describe the surveyed object. The research presented was motivated by the concrete need of archaeologists to identify and map the building functions and materials of heritage structures. To address this need, we developed a method to (i) distinguish different construction techniques, (ii) recognise the presence of specific materials, and (iii) assess their percentages and distribution over the investigated surfaces. Detecting these types of information in historical buildings using traditional methods, such as manual mapping or simple visual examination by an expert, are time-consuming and laborious procedures [Corso 2017]. Therefore this proposal aims to pave the way for less time-consuming solutions and the involvement of specialised personnel while still guaranteeing an accuracy compatible with the objectives of the research.

Case Study

Ponte Rotto is part of the Via Appia, a fundamental road that connected Rome to Brindisi and the East, defined by classical historians for the importance of the route as the regina viarum. The bridge crossed the river Calore near the ancient city of Benevento, on the way to the ancient *Aeclanum* [Aurigemma 1911, pp. 355-359]. It straddles the municipalities of Apice (BN), Bonito (AV) and Venticano (AV). The structures can be traced back to a viaduct bridge from Roman times and cover a chronological span from the 1st BC to the 7th AD, within which at least four different building techniques can be identified, referable to as many historical phases.
Nowadays, only three piers and one archway are preserved, however, historical sources have described six arches (from 10 to 22 m wide) with a total length of 190 m and a variable height of up to 13 m [Galliazzo 1995; Johannowsky 1991]. It was one of the most important bridges in Campania because of its size, unfortunately it has been in a state of neglect in recent years. The bridge was restored in Longobard Era, with the addition of concrete pillars aimed at supporting wooden arches that replaced the collapsed arcades. This intervention, due to the state of degradation of the structure likely aggravated by floods and overflows of the Calore river, was no longer sufficient in Medieval times, when the crossing was moved on a smaller bridge built with recycled materials of the same Hadrian bridge [Santoriello 2014; Santoriello 2018]. However, the bridge has been abandoned for centuries, experiencing carelessness and weathering that have resulted in a bad state of conservation. Actually, the monument in 1980s was interested by restoration and consolidation works with the addition of concrete pillar reinforcements [Quilici 1996]. Since 2011, several institutions, namely DISPAC (Department of Cultural Heritage Sciences) and DICIV (Department of Civil Engineering) of the University of Salerno, started a multidisciplinary project (Ancient Appia Landscapes) for the study and valorisation of the Appian Way. One of the first studies in 2017 was an aerophotogrammetric survey by UAV whose results were used for lithological and damage estimations. This paper describes the results of the photogrammetric survey that allowed the construction of a three-dimensional model of the *Ponte Rotto*, used to estimate – in automatic mode – the geomaterials quantity of the different architectural portions of the monument.

Photogrammetric Data Acquisition and Elaboration

In May 2017, the bridge was surveyed, and the photogrammetric results were used for the lithological assessment. Details of the analytical approach adopted for the study are given below. The tests carried out on *Ponte Rotto* were aimed at validating the photogrammetric acquisitions from UAV, namely a DJI Phantom 4, a drone weighing about 1400 g, capable of shooting 4K video at up to 30 frames per second and streaming HD video to smartphones, tablets and external devices through a special App (DJI Go).
The camera is equipped with a 12 MPixel Sony Exmor sensor (sensor size 6.3 × 4.7 mm, pixel size 1.56 µm), which has a wide-angle lens with a focal length of 4 mm and FOV (Field of View) of 94°. The camera integrated in the gimbal maximises image stability during filming. To geo-reference and control metric error, six ground control points (GCPs) were placed on the ground and measured by a global navigation satellite system (GNSS). The GCPs were materialised 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 [Barbarella 2014]. The accuracy of the planimetry is less than 1 cm and 2.5 cm for the altimetry. The photogrammetric shots were acquired in manual mode due to the presence of obstacles on the west side of the bridge (Fig. 1). Three flights were planned, and a total of 273 images, according to 3 consecutive strips, were acquired in time-lapse mode (5 s interval). In the first flight, 74 photographs were acquired in nadir mode (NW-SE direction, average height 19 m, ground coverage approximately 29.9 × 22.3 m).

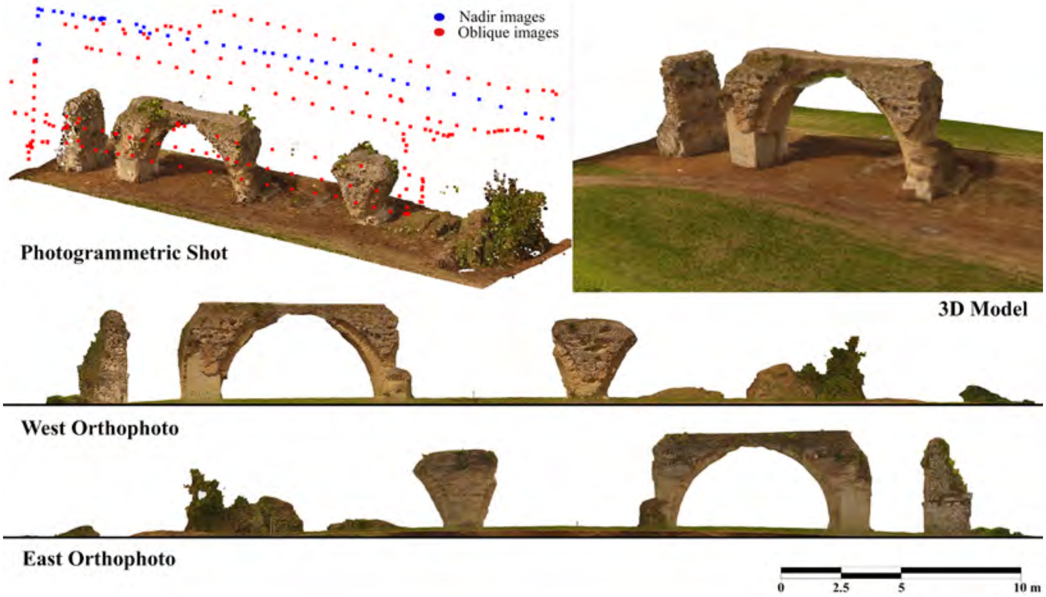

Fig. 1. Image acquisitions. Orthophoto West and East.

Then, two other flights, with the camera tilted at 45° in the horizontal plane, were carried out, acquiring a further 96 and 106 photos (17 m and 9 m on both sides; ground covers of approximately 26.8 x 20 m and 14.2 x 10.6 m, respectively). The aerial photogrammetric images were processed in Agisoft Metashape, version 1.7.3 build 12473.
The orientation parameters were estimated in Metashape, using a self-calibrating bundle adjustment (BA) by including the GCPs. These estimated parameters were then used to orient the images. Additionally, the estimated parameters were kept constant during the entire RGB data processing. The following parameters were set to calculate the point clouds: in the Align Photos phase, accuracy = High (original photos), Key-Point limit = 60,000 and Tie-Point limit = 40,000. To optimize the camera alignment process, f (focal length); cx and cy (principal point offset); and k1, k2, k3, and k4 (radial distortion coefficients) were fitted. In the building of the Dense Cloud, the parameters used were as follows: Quality = High (1/4 of original photos), and Depth Filtering = Disable; once the complete elaboration of the photogrammetric shots were done, it created the texturized 3D model of the bridge, used to extract the orthophotos of elevations, required for the next calculates needed of the geomaterials that compose it (Fig. 1).

Pixel-Based Segmentation

The applicability of supervised machine learning (ML) algorithms for accurately segmenting pictures was studied in this work. Supervised machine learning creates models in which machines are trained with labelled data (i.e., input data already tagged with the appropriate output) and then predict the outcome based on that data. In supervised learning, the training data presented to the machines acts as a supervisor, instructing the machines on how to anticipate the output accurately.
WeKa (Waikato Environment for Knowledge Analysis), developed at Waikato University in New Zealand, is one of the most well-known workbenches for data mining, employing machine learning to accomplish pixel-based segmentation. Contains a variety of data analysis and predictive modeling visualization tools and algorithms, as well as graphical user interfaces enabling quick access to these operations [Bouckaert 2010; Witten 2002]. Data preprocessing, regression, classification, visualization, clustering, and feature selection are just a few of the usual data mining operations that WeKa offers.
The Trainable Weka Segmentation plugin (TWS) was used to train a classifier, then used to

segment the remaining validation data automatically. The ImageJ plugin is a collection of picture segmentation and machine learning techniques included in the open-source image processing program Fiji and can be installed on the free-access software ImageJ. [Arganda-Carreras 2017].
Pixel-based segmentation is performed using the Fast Random Forest method, a parallel version of the Random Forest classification approach [Breiman 2001; Ho 1995]. Random Forest is a versatile machine learning technique that can be used to a wide range of problems, including regression and classification. It comprises a number of decision trees, each of which represents a unique categorization of data fed into the random forest. The random forest method evaluates each occurrence separately, selecting the one with the most votes as the chosen prediction.
Each classification tree uses samples from the initial dataset as input. The features are then chosen at random and utilized to build the tree at each node. No tree in the forest should be trimmed until the exercise is completed and the prediction is made definitively. Random forests can also handle large datasets with a high dimensionality and a wide range of features. Using a training set of manually annotated images, the Fast Random Forest algorithm is first trained by examples in a supervised manner. Each pixel in these images has been individually labeled with its matching label. Then, the original image is presented to the model in each of these cases, which computes the actual answer. Following that, the model's weights are changed to minimize the difference between this answer and the annotation that reflects the model's predicted answer. Finally, the model's performance is evaluated by comparing it to a different collection of photos than those used during the training phase. When the segmentation is successful, the result is overlaid with the matching class colors just over the original picture. The random forest method was chosen for image segmentation tasks in various disciplines for its accuracy, speed, and multi-class segmentation capabilities. [Belgiu 2016; Mahapatra 2014; Smith 2010].

Result

The bridge was built with different techniques and geomaterials, as observed in other coeval monuments in Benevento [Grifa 2007], which basically depend on the structural function they had. Lithological mapping highlighted the presence of tuff material, bricks and limestones welded by mortars (Fig. 2; Table 1). Concrete, due to recent restoration works, also occur (Fig. 2).
From the analyses carried out by experts in petrology and petrography, it is possible to identify 4 macro-groups of materials for the construction of the bridge: yellow tuff, bricks, limestone and cement. The yellow tuff material is the predominant building stone in both eastern and western façades (23 % on average, Table 1), covering the lower part of the bigger lateral pillar and the central circular arch.
Yellow tuff can be attributed to pyroclastic trachytic rocks (likely Campanian Ignimbrite in Yellow facies), one of the first building materials since Roman times, largely used for other coeval historical monuments of Campania region [Morra 2010], also outcropping along the Calore river [Vitale 2018], as also observed in nearby contexts [Cilenti 2019].
The framework of tuff blocks is made up in opus incertum, intercalated with bricks. Bricks (8 % on average, Table 1) were used as covering material in the upper part of all the elements of the bridge (arch and pillars). They are generally horizontally oriented (except for the archway where they signed the arch shape).
Limestones, occurring in different percentage on both sides (17 % on average, Table 1), have been recognized as large squared limestone blocks on the base of the pillars of the archway, and fluvial pebbles superimposed on the archway.
It should be remarked that a significant surface of the bridge (eastern façade 11.0%, western surface 6.5%, Table 1) was not investigated due to the presence of plants mainly growing on the top and the bottom of the façades.

Façade	Tuff	Brick	Limestone	Cement	Mortar	Not observable
Western						
Manual Analysis	23.2%	8.5%	17.2%	4.6%	40.0%	6.5%
ML Analysis	30.8%	17.8%	38.2%	4.9%	/	8.5%
Eastern						
Manual Analysis	23.2%	10.1%	15.7%	4.6%	39.1%	11.0%
ML Analysis	27.2%	12.9%	34.7%	4.7%	/	19.6%

Table 1. Distribution by manual and ML supervised approach.

Mortar-based materials containing volcanic aggregate and covering around the 40% of the examined surfaces (Table 1) were used to bind the different building materials [Izzo 2016]. These mortar-based binders are highly dispersed within the orthoimages and difficult to bind to pixel-based macro-clusters.
Therefore, the classes analysed by supervised ML algorithms only considered the four macro classes listed at the beginning of this paragraph. From the analyses carried out using ML algorithms, it can be seen that there is an overestimation of the percentage for each class of material compared to the more exact manual techniques.
The principal reason for this is the presence of mortar; in fact, the greatest overestimates occur where mortar is greatest in point form, i.e. in the top part of the bridge, where the geomaterials there are a strong predominance of Limestone. Therefore – as a percentage – the ML analysis for Limestone has a very high error percentage (average error ratio of 2.2 times the percentage estimated by manual techniques).
The best estimates of quantity are for the brick (average error ratio of 1.68) and for the not observable part (average error ratio of 1.54), which are affected by high overestimates due to the participation of point mortar in the areas where these classes have been identified.
The best estimates of the quantity of materials occur where these are continuous and without the presence – at least not excessively punctual – of mortar, i.e. for yellow tuff (mean error ratio of 1.24) and cement (mean error ratio of 1.04), where the percentages estimated by ML algorithms can be considered acceptable.

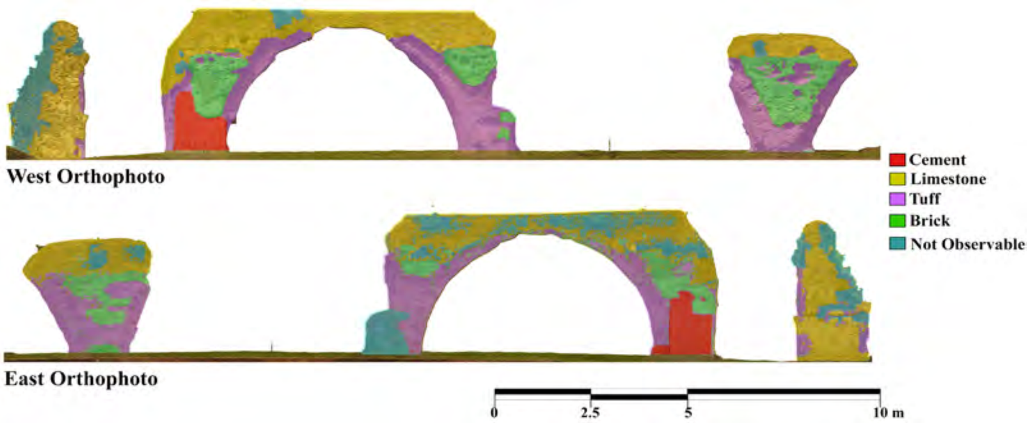

Fig. 2. Geomaterial distribution by ML supervised approach.

Conclusion

This work aimed to evaluate the detection of different geomaterials within high-resolution orthophotos generated from 3D photogrammetric models, in this case, specifically from UAVs in the *Ponte Rotto*. The applicability of supervised machine learning (ML) algorithms to accurately execute multi-class segmentation on images at a pixel level – in particular, the WeKa algorithm used in this study implementing the Fast Random Forest method – highlighted some limitations in the presence of point and irregular lithotypes within the orthoimage that are present in this work with the specific case of the mortar geomaterial. From the experimentation carried out in this investigation, even the use of the same orthophoto but at higher resolutions (the one used for the calculations has a resolution of 1 cm, tests were carried out for 0.8 and 0.5 cm) did not lead to gross improvements or acceptable percentages of recognition of that type of geomaterial that carries to a minor difference with the manual analysis.

On the other hand, in the case of compact geomaterials – as was the case of the yellow tuff and cement – continuous along the image surface, the estimations made by the ML algorithm are very close to those analysed by comparison with calculations made in previous works with experienced personnel. Therefore, better results can be obtained for ortho-image studies in which the materials do not have punctual variations, but are arranged continuously along a surface, as is generally the case for building facades.

In fact, specifically in facades characterised by continuous and linear material layers – as already known from other studies cited in the text – in the realisation of clusters, the proposed machine learning algorithm manages to define better the portions of materials characterised by different textures, obtaining better results in the differentiation of geomaterials, and accomplishing percentages of each type that are in agreement with those obtained manually by an expert, reaching a less time-consuming and laborious solution. As future works, subsequent studies will be carried out – always in archaeological contexts – on case studies where the texture is homogeneous in layers, verifying the accuracy in clustering the orthoimage. Subsequently, the orthoimage will be reprojected on the starting point cloud, in order to obtain for each 3d point a "scalar field" relative to the material to which it belongs.

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Proposal for a Data Visualization and Assessment System to Rebalance Landscape Quality

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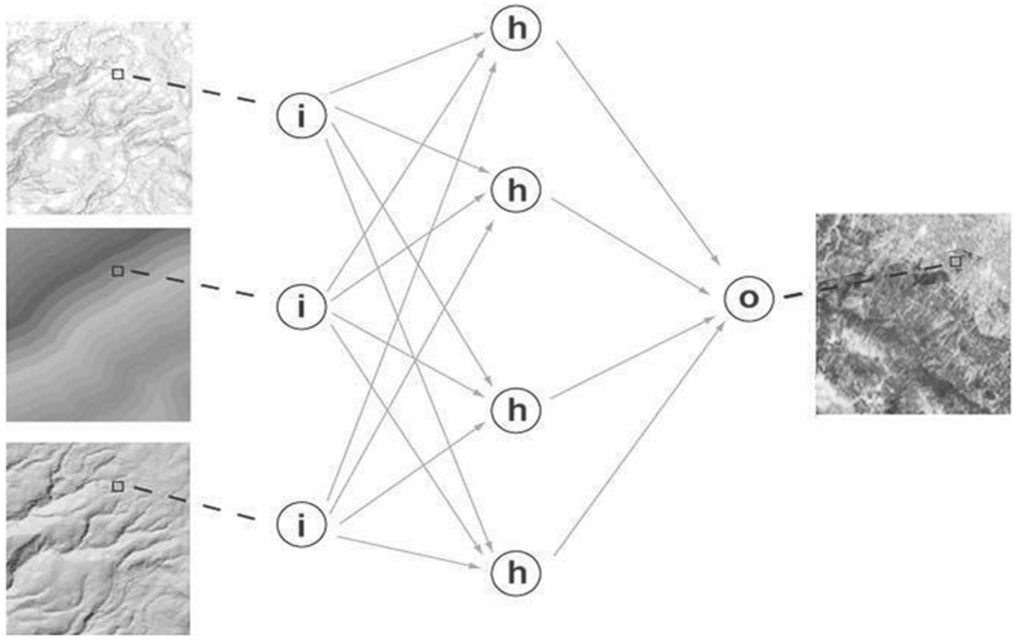
Abstract

The landscape can be considered a complex system described as a non-linear entity, organized according to the connections between the different elements that characterize its state. The latter cannot be determined a priori but emerges from the multiple interactions between assets and relationships that are no longer found when the phenomenon is traced back to the individual components. Territorial development is closely connected to social, economic, cultural and symbolic issues that determine the transformative practices of space and the territorial palimpsest. If not carefully managed, these forces can lead to the dissolution of the landscape and environmental values that have been stratified in a specific land. This paper proposes the construction of a numerical spatial model that describes the territorial settlement patterns, based on methodologies and techniques typical of AI, to develop tools for re-balancing the man-landscape relationship.

Keywords
AI, complex systems, emergent behaviours, landscape design.



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Introduction

Representing a territory pattern is an interdisciplinary research subject because it requires the detection, analysis and understanding of different and interdependent issues related to human settlement. The latter leaves visible signs, which determine specific landscape conformations, as result of the settlement stratification choices of the past.
Several research have defined the shapes of settlement meshes, traceable to patterns derived from spatial determinants (climatic factors, hydrography and land morphology, administrative structure and resource exploitation, etc.), without dwelling on possible alternative responses, which were of little significance before the development of objective assessment tools.
The landscape is, in fact, a complex system in continuous search of equilibrium, describable as a non-linear entity, organized according to the connections between the different elements that characterize its state. The latter cannot be determined a priori but emerges from the multiple interactions between assets and relationships that are no longer found when the phenomenon is traced back to the individual components. Today, Artificial Intelligence allows the evaluation of multi-factorial parametric models' development in long-term dynamics, which enables to prefigure choices in anthropic policies. However, the landscape transformation determinants are multiple and fragmented in an abnormal amount of heterogeneous information in shape and size, which makes it difficult to represent them in context and thus the necessary interpretation for the efficiency and sustainability of interventions (projects).
The emerging phenomena that arise in complex systems are highlighted using computers to explore the possibilities and limits of developing increasingly articulated models. Awareness of the complexity of urban and regional dynamics, based on spatial interaction, makes it possible to appropriately identify interventions of different scales capable of selectively intervening by rebalancing the system and contributing to the improvement of territorial quality.
Realizing predictive digital twins requires survey data representation systems to interpolate the 'visual' information stratified in the landscape with the otherwise acquired information. Beyond the description based on direct observation of places (classic cartography, geo-referenced information systems-GIS), the territory is daily digitized by thousands of photos, videos, comments and annotations processed in real-time through personal devices. In addition to this, there is a multitude of data derived from the Internet of Things, or Networks of Objects, connected to the information structure in a continuous exchange of information about the surrounding environment.
The AI makes it possible to deal with this complexity by constructing probabilistic models that identify among thousands of data those significant about a specific problem, reconstructing the patterns of optimal organization with Machine Learning techniques based on Neural Networks (Fig. on front page). These use mathematical-computational methods to extract knowledge directly from alphanumeric data, images or any other digitizable format, without the need for explicit predefined rules. Applied to spatial analysis, they can highlight hidden links between the various elements of anthropogenic space, aiding understanding of the principles that shape and evolve a given landscape and facilitating its planning and development.
So that a Neural Network could be used to solve complex problems of deterministic or stochastic order, it should be trained with a set of data significant to the understanding of the phenomenon analyzed. The study and selection of the information that correctly represents a territory is the first step for any machine learning model aimed at an outcome.
Therefore, we propose a research purpose based on construction of a numerical spatial model that describes the territorial settlement patterns, based on methodologies and techniques typical of AI, to develop tools for rebalancing the man-landscape relationship. This goal requires defining the semantic organization and methods for collecting and integrating data into a syntactic structure of predictive representation, based on three nested and interconnected levels, understood as the central dynamic components that condition the visual organization of a territory as a complex system:

– the physical level of matter and energy,
– the logical level of information and representations,
– the identity and self-referential level.

The first level concerns the resources and processes recognized and more or less regulated for their exploitation; the second involves the presence of elements referable to the population; the last qualifies the identity space through architecture, which expresses the symbols and shared social norms of a shared vision expressed through the physical signs that consolidate a specific culture.

Territory as a Complex System

The science of complex systems, which has emerged in recent decades under the computerization acceleration, renounces the assumptions of linearity in dynamical systems to investigate their real-world behaviour in greater depth. The main field of interest is the behaviour that specific systems exhibit when they are far from stability, giving rise to dynamics of self-organization and adaptation describable according to rules shared by physical-chemical, biological, social, natural or artificial phenomena. The suggestion of some theories advanced in the field of complexity has produced over the years an epistemological debate that makes it problematic to define a precise frame of reference. Complexity science [1], theory of chaos, theory of complex systems are terms often used spuriously in journalistic circles and customs with meanings that move away from the scientific context to venture into colloquial areas.
Systematics is not, as too often reported, a new branch of science but rather a different vision of the scientific method that questions the research model prevalent today. The latter can be traced back to the cultural revolution of the Renaissance, when the scholastic was gradually replaced by the empirical-rational model based on the observation of nature and logical-mathematical description. According to this paradigm, any phenomenon, however articulated, can be understood by reducing it to a sum of specific and more comprehensible parts, then assembled by unifying the individual observations into a single absolute value theory.
Nevertheless, the systemic view sees the world as an irreducible dynamic system, consisting of networks of interconnected systems, interdependent and inseparable, which also includes human action. Regardless of their natural or artificial origin, complex systems are therefore determined by relational laws, which exist as an interaction between the elements of a particular structure and not at the individual element level. From the mutual interaction of components and factors acting on the system, emergent behaviours develop, leading to organizational forms that cannot be determined a priori. A typical complexity issue is the three bodies problem [2] faced by Henri Poincaré [3]. The phenomenon does not admit an analytical solution, therefore deterministic, because, although describable by known equations, it diverges unpredictably after a certain period. In other words, with the same values and maintaining the same mathematical formulations, different results are obtained at each recalculation.
Poincaré's observation is recognized as the general theory of complex system birth, but we must wait for the studies of Ludwig von Bertalanffy (1968) and Heinz von Foerster (1981) and the advent of cybernetics, initiated by Norbert Wiener (1948) and William Ashby (1956), for the construction of a rigorous systemic approach. Wiener extends the potential of logical-mathematical models to the description of social systems, conceived as ensembles in which the interaction, continuous and changing, between matter, energy and information takes place (see Fig. 3). The morphology that a territory assumes is therefore not necessarily a consequence of prior planning: individuals, families, industries, religious groups are entities that choose and interact in non-linear ways within society, understood as the gradual result of the experience accumulated by several generations, in a process of continuous learning based on the flow between the available materials, the

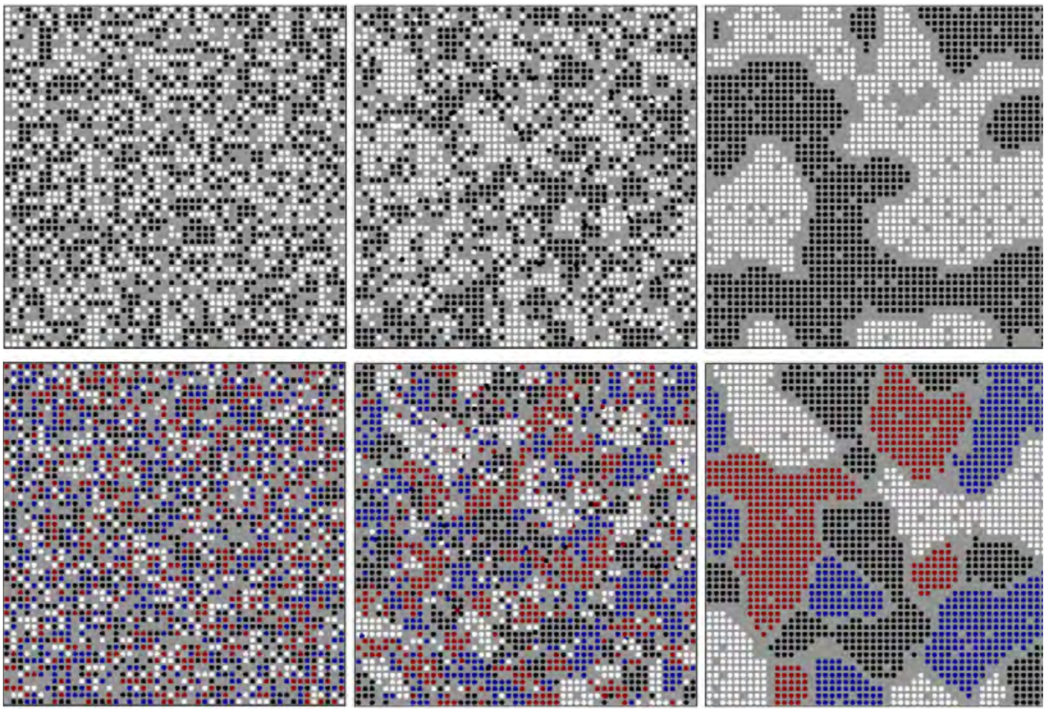

Fig. 1. The dynamics of the Schelling model: individuals of a specific type (e.g. ethnicity, religion, political view, etc.) migrate to different locations: An initially mixed population segregates, after some time, into patches of uniform type. The same behaviour is also obtained as the number of ethnic groups increases (*below*). (https://www.complexity-explorables.org/slides/t-schelling-plays-go/)

energy necessary for their transformation and the exchange of information that contributes to the evolutionary processes of the economy [Fujita, Krugman, Venables 2001]. A significant example of systemic concepts application to spatial analysis is Schelling's segregation model [Schelling 1971; Schelling 1978] based on the observation that almost all US metropolitan areas are characterized by neighbourhoods inhabited almost exclusively by whites or only by people of colour. It is not easy to find areas where both groups exceed three-fourths of the total population.

To analyze the phenomenon, Schelling developed a two-dimensional cellular automaton[4] in which the territory's surface under consideration is divided into square cells, each corresponding to an individual or a household. The cells can be vacant or identified according to a colour attributed to the individual's ethnicity occupying them. Each individual (or household) can thus have from zero (neighbouring cells all uninhabited) to eight (neighbouring cells all inhabited) neighbours. The system is then implemented through a set of rules that determine when an individual is 'happy' or 'unhappy' with his or her home, based on number and neighbourhood [5].

Suppose during the evolution of the system the condition is not respected. In that case, the occupant moves to a new dwelling in the nearest vacant cell [6], thus influencing both the habitat he leaves and the one he enters since the displacement will condition the preferences of both old and new neighbours.

Given an initial configuration of the model, in which the ethnic groups are randomly distributed over the territory, it is observed that after a few iterations, the cells aggregate into large homogeneous groups, distinct by ethnicity (Fig. 1). The system, therefore, from a disordered state, operates an actual phase transition [7] towards an ordered state of equilibrium, reached when segregation zones form.

If the ethnic groups are allocated according to a chessboard arrangement in the initial moment, the system instead maintains a state of dynamic equilibrium: all individuals remain where they are. Interestingly, the introduction of a few localized perturbations, such as changing the colour of a small number of cells at random, reactivates the dynamics of relocation that leads to segregation (Fig. 2). Despite its simplicity [8], the model reveals a form of endogenous self-organization of the territorial system, where the interaction between individual choices leads to collective results.

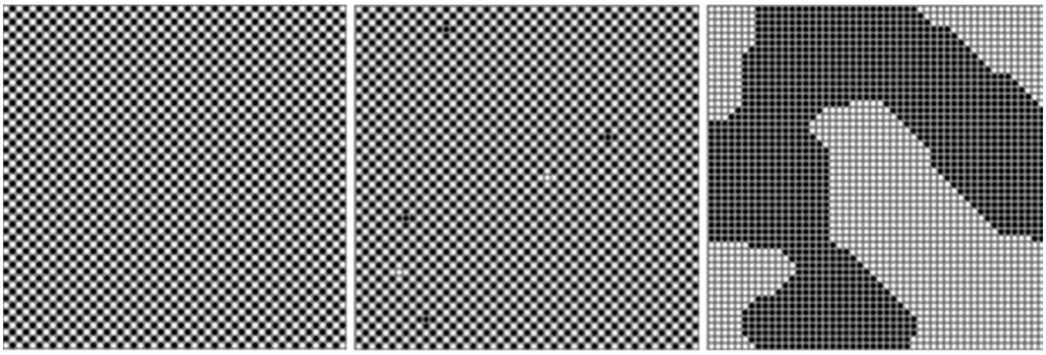

Fig. 2 Chessboard arrangement in the initial moment: the system maintains a state of dynamic equilibrium. The introduction of a few localized perturbations, changing the colour of a small number of cells at random, reactivates the dynamics of relocation that leads to segregation.

The formation of ghettos results as an emergent phenomenon due to the process of self-organization that follows the locational choices of individuals, regardless of any radical positions they may hold. In the model, no individual thinks in a dirigiste way of establishing organized segregation, so much so that the system is initially disorderly. Even when the degree of tolerance is high (37% of similar neighbours), local interest determines broad zones of separation at higher system levels. A close reciprocal relationship is implemented: people and social dynamics influence the built environment which, in turn, influences people and society.
Clearly, it cannot be assumed that the self-organization of a system, as itself, necessarily leads to a desirable outcome [9]. Leaving aside natural systems, where such evaluations are not relevant, it is a prejudice to suppose that spontaneous and self-organizing order is necessarily the best outcome in the face of the unstable equilibrium from which it originates. Considering the territory as a complex system can, however, promote a design capable of restoring the system's equilibrium, should this be broken by causes of any nature, replacing the failed managerial vision applied since the post-war period, which sees the anthropic environment as a disorganized system to be redesigned using homologated and predefined schemes.

Method and Goals

New forms of survey restitution allow an effective description in terms of dynamics models underlying the territorial evolution. According to the complexity approach, the study of appropriate modelling is based on the endogenous mechanisms, linked to agent choices, that lead to the system's configuration. Agents (individuals, households, enterprises) interact through the network that connects them to exchange information, goods and resources, to establish new partnerships, collaborations, friendships and more. A territory can thus be described as a network of connections between different socio-economic determinants, in which links are changeable and diffuse in space and evolve over time towards a hierarchical organization. Thanks to particularly effective interactions between energy, material and information with local geographical features, some of these networks are configured into particular recognizable settlement systems and reduce the various morphological occurrences to a manageable number of types. Industrial districts, for example, are specialized, organized settlements located in areas of limited size, which are characterized not only by the availability of particular materials and energy, but also by the sharing of experiences through an active communications network at a social level (so-called intangible capital) and by continuous, widespread interactions between the parties. Therefore, the resulting territorial reality is self-organizing, challenging to achieve with external dirigiste regulatory actions [Corò, Micelli 2008].
Formally representing the relationships on which the built environment depends, to model and manage the different flows to guide them towards predefined goals is not an obvious process. The problem goes beyond the morphological issue, it is closely connected to social, economic, cultural and symbolic issues that together determine the transformative

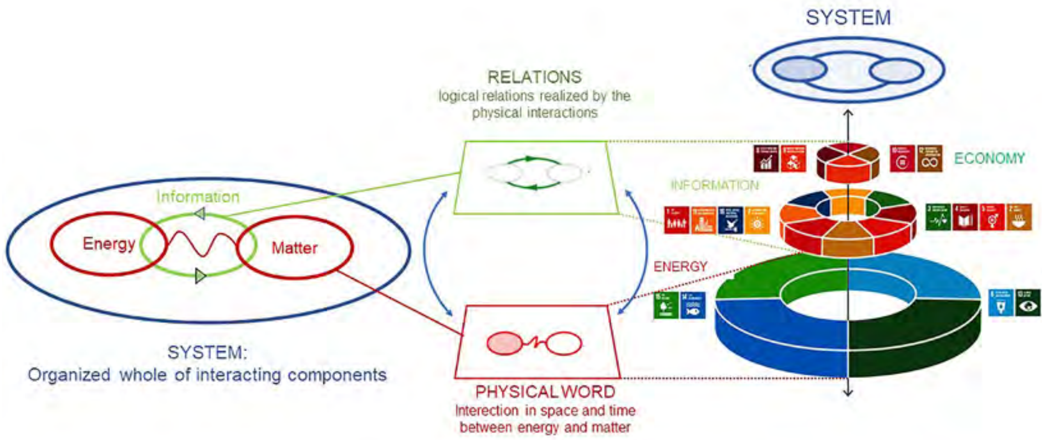

Fig. 3. Sustainable Development Goals related to the matter, energy and information scheme derived from cybernetics theories.

practices of space and how new elements modify the pre-existing configurations of the territorial palimpsest. If not carefully managed, these forces can lead to the dissolution of the landscape and environmental values that have been stratified in a specific territory.

The behaviour of these forces is parcelled out in many data and information heterogeneous in type and size, which, if examined by man, would require the commitment of a large number of people over a long time.

It is necessary to use an AI capable of sifting through this multitude, even admitting partial or incomplete data, to identify the relationships between territory, resources, and the various settlement realities. By observing and comparing the results diachronically, it would be possible to visualize the system evolution, highlighting the continuities, discontinuities and possible interruptions that characterize them, allowing the visual representation of otherwise abstract concepts.

In particular, the simulation requires a neural network model based on fuzzy logic will be configured, which can be used to solve both deterministic and stochastic problems. The process will be conditioned by moments of "training", during which data significant to the problem understanding being studied are input, followed by new data, whose possible output is unknown, to obtain effective solutions based on the previous phase.

The realization of such a large and complex synthesis model requires the achievement of secondary objectives:

a. Definition of a procedure enabling the AI to recognize spatial data, in the first instance those available in databases related to the application of geographic information systems (GIS), summarized as:

– geometric, relating to the cartographic representation of the objects represented.
– topological, referring to the mutual relationships between objects.
– informative, concerning the data (numerical, textual, etc.) associated with each object.

The GIS databases are usually in vectorial formats, more suitable for the representation of information that varies discretely (e.g. the location of waste bins in a city or the representation of roads or a land-use map), and raster formats more suitable for the representation of data with continuous variability (e.g. a digital elevation model or a slope acclivity map). These data will have to be integrated as far as possible with other sources, both of a documentary and archaeological nature. They will require the definition of symbolic schemes that make it possible to treat historical-archaeological data in numerical form.

b. Study of the energy-materials-information domain by identifying several notable areas, chosen on the basis of the United Nations Development Goals [10]. These are universally valid, i.e. all countries must contribute to achieving the goals according to their capacities and take into account the three dimensions of sustainable development, economic, social and ecological, in a balanced manner. The comparison between the different forms of settlement and these parameters, by identifying differences and similarities, within the investigated territory will make it possible to analyze spatial relations and inductively determine the possible outcomes of political and planning choices, anticipating the effects.

Attributions

Although the article must be considered a collective work, Michela Rossi was responsible for the Intro, Giorgio Buratti wrote the second paragraph (Territory as a complex system) and Giorgio Buratti and Sara Conte wrote the third paragraph (Method and goals).

Notes

[1] "Complex" descends from the Latin verb ***complector***, meaning to gird, to hold tightly, and, in a metaphorical sense, to embrace, to understand. Other meanings used in the Latin classics are bond, nexus, concatenation.

[2] The three bodies problem consists of calculating, given the initial position, mass and velocity, the system's future evolution consists of three bodies subject to mutual gravitational attraction. If in the case of two bodies, the evolution of the system is entirely determined by simple equations, if a third body is added to the system, this last is no longer describable analytically or only for particular cases, since each displacement of a body simultaneously influences the displacements of the other two. The introduction of the computer has allowed over the years a greater control of the system's evolution, which is now predictable for longer and longer periods with the adoption of simplifications. However, at the writing of this article, the problem is not yet definitively solved.

[3] In the pioneering study on the qualitative theory of differential equations, published between 1881 and 1886, Poincaré discovered that the existence of a doubly asymptotic solution led to infinite others, which intersect infinite times, forming a tangle that Poincaré did not even try to draw. Although he did not pay much attention to the disorderly behaviour he discovered, Poincaré was deeply disturbed by it; almost ten years passed before he returned to publish something new on the subject. This type of motion is now called 'chaotic'.

[4] A cellular automaton is a mathematical model used to describe the evolution of complex discrete systems, studied in the theory of computation, mathematics, physics and biology, consisting of a grid made up of cells. The grid can have any finite size; each limited portion of space must contain only a finite number of cells. Each of these cells can assume a finite set of states and, after a fixed time, changes state simultaneously with all the others, according to a fixed rule.

[5] For example, one is 'happy' if at least 37% of one's immediate neighbours are of the same ethnicity, a condition for which one does not leave the cell.

[6] The preference for similar characteristics or interests is very marked and widespread in all cultures and has a strong instinctual connotation. It is clear that the relationship between this propensity and racism or just residential segregation is very intricate and still far from being definitively clarified and agreed upon. One could, for example, observe that the difference in income may have a more significant influence, but this kind of recognition would imply a more articulated analysis, whereas ethnic distinction requires only the recognition of somatic features, clothing or eating habits.

[7] In physics and chemistry, a phase transition is the transformation of a thermodynamic system from one state of aggregation to another, with a consequent change in one or more physical properties. The best-known phase transition is the transition from the solid (ice), liquid and aeriform (vapour) state of water.

[8] The segregation/integration relationship could also depend on other variables such as: the size of the city; the percentage of free cells; a different number of neighbours; different settlement patterns; possible costs of moving (relocation) to other areas; the value of the urban rent and its variation according to the prevalence of one group rather than the other, and so on. However, studies conducted in the following years, which have considered these and other variations, align with Schelling's outcome. The only research that has so far led to different conclusions is the model of E. Bruch and R. Mare (2006), which departs from the original model in terms of a larger grid, tolerance degree diversification for different agents and allowing entities to return to occupy a cell they have already left. However, it is sufficient to eliminate the last condition for this model to return to the segregationist model too.

[9] If, for example, a group of people decide to sell stocks in the equity market, in the absence of a cause attributable to economic fundamentals that rationally justifies the decision, then the previously disorganized market, in a stable balance between requests to sell and requests to buy, organizes itself towards a continuous fall, leading to a financial collapse.

[10] In September 2015, more than 150 international leaders met at the United Nations to contribute to global development, promoting human well-being and protect the environment. The community of states endorsed the 2030 Agenda for Sustainable Development, the essential elements of which are the 17 Sustainable Development Goals (SDGs).

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Point Cloud Segmentation for Scan to BIM: Review of Related Tecniques

Devid Campagnolo

Abstract

The creation of as-built BIM models sees in the scan to BIM modeling one of the most time-consuming activities. Scan to BIM modeling refers to the creation of BIM objects from information derived from point clouds acquired through laser scans or photogrammetric techniques.
Numerous studies have been conducted in recent years to identify automation or semi-automation procedures for the scan to BIM modeling process, which consists of different aspects: the recognition of objects within the scene, the modeling of their geometry and the recognition of the relationships between them.
The present work aims to analyze actual trends in the automation of scan to BIM activities, highlighting the most used approaches and methodologies currently presented in order to provide a key to understanding the development of a theme still at the dawn of its expression.

Keywords
BIM, point cloud, scan to BIM, machine learning, review.

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Introduction

The development of as-built BIM models from point clouds, acquired through laser scans or photogrammetric techniques, is a process that consists mainly of three activities [Tang et al. 2010]:

1. The recognition of the objects present in the scene
2. Modeling the geometry of recognized elements
3. The recognition and definition of the existing relationships between the elements

The automation of this process consists of the automation of the above-mentioned activities, which can be translated into point cloud segmentation activities (1) and activities of geometry extraction from point clouds (2 and 3). The complexity of the task consists in translating the result of these activities into the logical structure of the BIM methodology.
The study focused on the analysis of the studies carried out on the extraction of information from point clouds for the purpose of creating three-dimensional digital models, with particular attention to BIM models.

Methodology

An analysis was carried out, using Scopus database, on the articles published from 2010 to 2022 which presented as search keys the words: "Segmentation", "Point Cloud", "BIM", "Scan" (Fig. 1).
Of the documents thus obtained, the information concerning: Author, Title of the document, Year of publication, Citation count, DOI, Publisher, Abstract, Autor keywords were extracted from the database.
The OSViewer software was used for a preliminary analysis of the information obtained, then Python code was used to analyze the presence of specific keywords chosen by the author.
The analysis technique used involves searching specific keywords through the keywords and the abstract of each article. The algorithm, written in Python, pre-processes the string representing the abstract and the string representing the keywords by reporting all the characters in capital letters and eliminating the characters "." , "-" and " "(space). The analysis on the presence of the keywords is then performed on the strings thus transformed. This presence is counted only once for each record in order to not suffer distortions in the results due to the possible presence on several occasions of the same keyword on the same article.

Results

The analysis conducted on the Scopus database produced 518 results of articles related to the above filters. The same search was carried out selectively on different keywords:

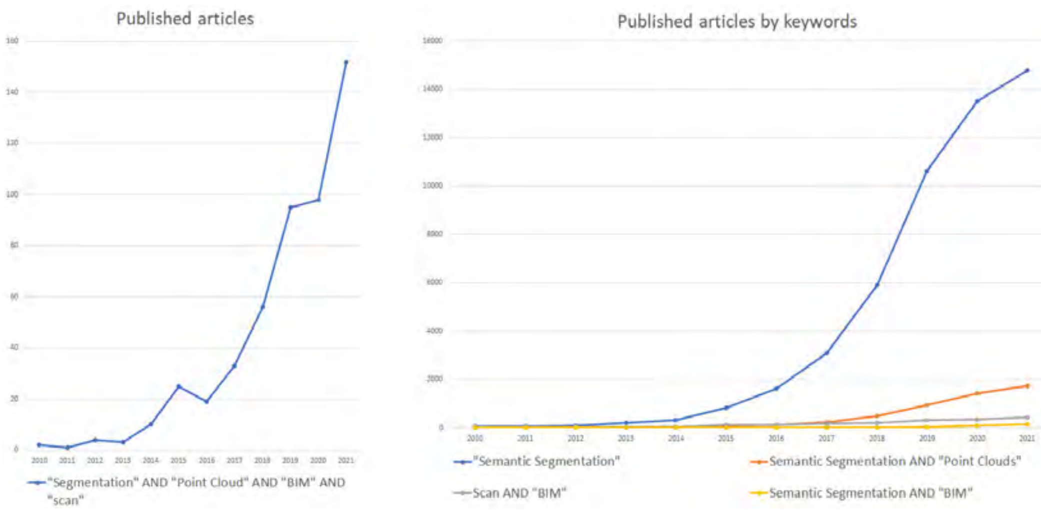

Fig. 1. Published articles referenced to key words.

“Semantic Segmentation”, “Semantic Segmentation” & “Point Clouds”, “Scan” & “BIM”, “Semantic Segmentation” & “BIM”. The analysis shows how the segmentation of point clouds for activities related to BIM modeling, despite appearing to be a field in strong growth in recent years, is still at an embryonic stage compared to the research carried out on semantic segmentation of point clouds and this fact appears even more markedly in reference to research on semantic segmentation in general.

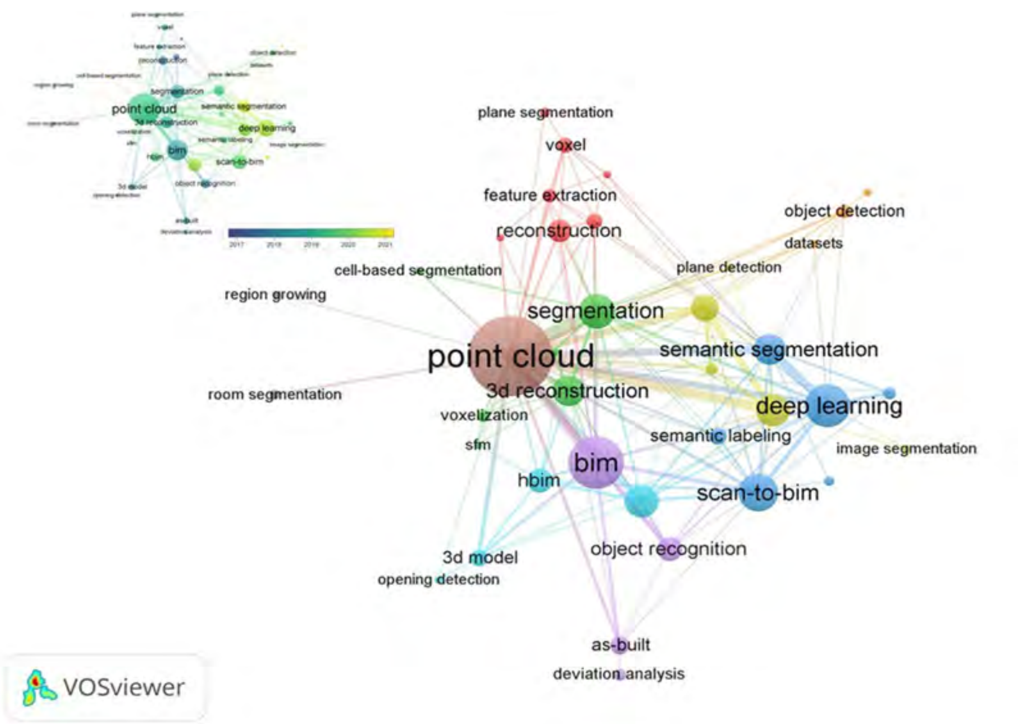

Fig. 2. Graph of recurrent themes produced whit VOSviewer software.

The processing of data through the OSViewer software produced the maps represented in figure 2 which allowed a first evaluation on the techniques and themes most used and addressed in relation to the search keys (Fig. 2).
Of the 518 items considered, 226 articles are related to the keywords “BIM” or “Scan to/vs BIM”. An analysis of these articles was carried out in order to further aggregate the dataset according to specific themes. The first topic addressed concerns the decomposition of the dataset between the articles dealing with the segmentation of point clouds for activities related to the BIM methodology and the articles dealing with the semantic segmentation of point clouds in relation to the BIM methodology.

Segmentation Techniques

The segmentation of a point cloud leads to the subdivision of the cloud into non-overlapping regions, which represent specific structures or objects united by similar geometric characteristics. Point cloud segmentation can be done through the following approaches [Xie et al. 2020]:
- Edge-based
- Region growing
- Model fitting
- Clustering

The presence of such approaches in the database was analyzed using as search keys:
- EDGE BASED: EDGEDETECT, EDGEBASED, DETECTEDGE
- REGION GROWING: REGIONGROWING, SEEDPOINT

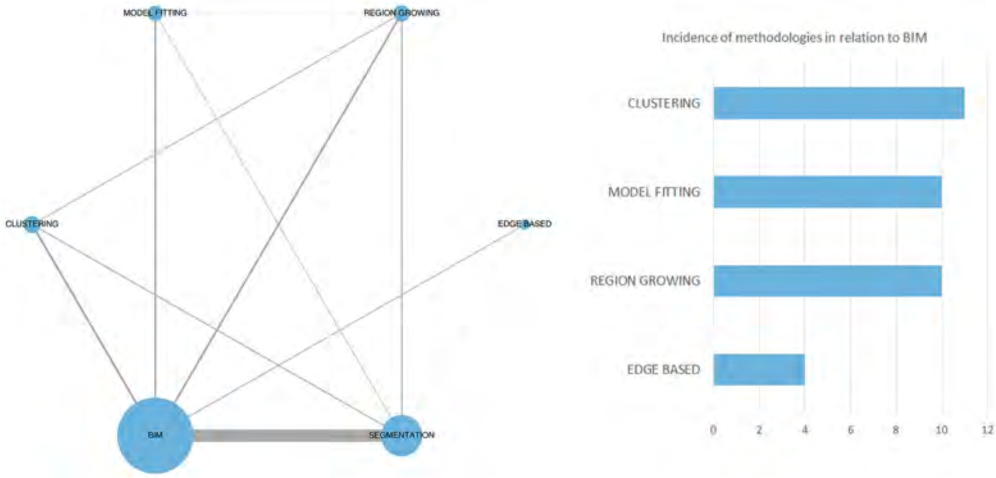

Fig. 3. Incidence of segmentation techniques.

- MODEL FITTING: HOUGHTRANSFORM, RANSAC, RANDOMSAMPLECONSENSUS, MLESAC, MSAC, PROSAC, HOUGHBASED, MODELFITTING
- CLUSTERING: KMEANS, MEANSHIFT, GRAPHBASED, FUZZY, CMEANS, KNN, KNEARESTNEIGHBORS, MARKOVRANDOMFIELD, CONDITIONALRANDOMFIELD, VCCS, BESS.

The size of the nodes represents the incidence of the key in the dataset, the size of the arcs is proportional to the number of times that two keys are detected together in the same record (Fig. 3).

Semantic Segmentation via Machine Learning Approaches

The semantic segmentation procedure generates, unlike the segmentation procedure, information about belonging to a certain class for each point, and is usually carried out through supervised machine learning models and deep neural networks (Fig. 4).
The approaches analyzed for the semantic segmentation of point clouds were first of all those concerning supervised machine learning models (excluding deep neural networks), which include [Xie et al. 2020]:

- Support vector machine (SVM)
- AdaBoost
- Cascade of binary classifiers (BC)
- Decision tree / Random Forests (RF)
- Bayesian discriminant classifiers (BDC)
- Markov networks (MN)

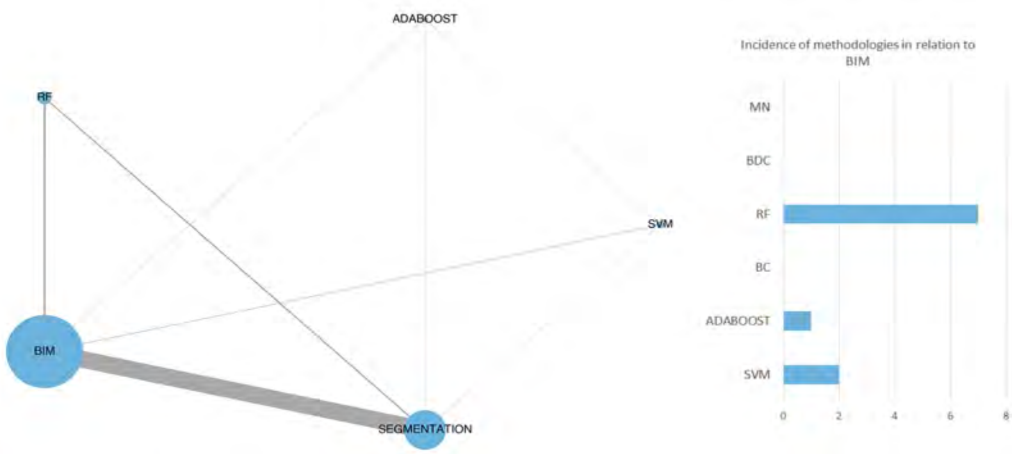

Fig. 4. Incidence of Machine Learning techniques.

The search keys used are:

- SVM: SVM, SUPPORTVECTORMACHINE
- ADABOOST: ADABOOST
- BC: BINARYCLASSIFIER
- RF: RANDOMFOREST, DECISIONTREE
- BDC: BAYESIANDISCRIMINANT, NAIVEBAYES
- MN: MARKOVNETWORK

Semantic Segmentation via Deep Learning Approaches

The approaches concerning the use of deep neural networks for semantic segmentation of point clouds are divided into three macro-areas [Xie et al. 2020]:

- Multiview based (MB)
- Voxel based (VB)
- Directly point processing (PB)

The Multiview based approach involves extracting a series of 2D views from the point cloud (Fig. 5). These views are then processed through convolutional neural networks. The main problems in the use of this approach lie first of all in the loss of spatial information that the transformation of a point cloud into a series of 2D views entails, secondly in the impossibility of realizing a satisfactory number of 2D views that can represent complex scenes.
The Voxel based approach involves the transformation of the point cloud into a three-dimensional matrix consisting of voxels, which is subsequently processed through 3D convolutional neural networks. The main problem inherent in the use of this approach lies in the loss of data that the transformation into voxel of a point cloud entails.
The most relatively recent approach involves the use of deep neural networks without pre-processing the 3D data, thus overcoming the main problem associated with the two previous methods, namely the loss of information that both types of pre-processing entail.
The reference of these methodologies in the database was searched using among the keys the names of the main network architectures developed in recent years (Fig. 6). The keys used are:

- MB: MVCNN, MULTIVIEW, VIEWBASED, 2DCNN, SNAPNET
- VB: 3DCNN, SEGCLOUD, VOXNET, FCNN, CRF, VOXEL
- PB: POINTNET, DGCNN, 3PRNN, POINTWEB, POINTSIFT, SPLATNET, RGCNN, POINTCOV, RANDLANET, RANGENET, CANUPO

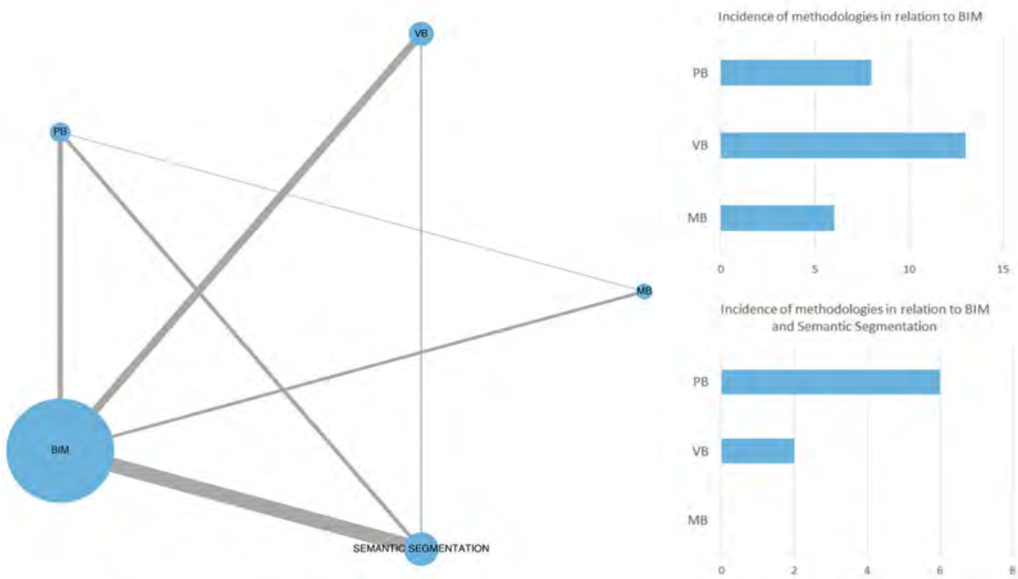

Fig. 5. Incidence of Deep Learning techniques.

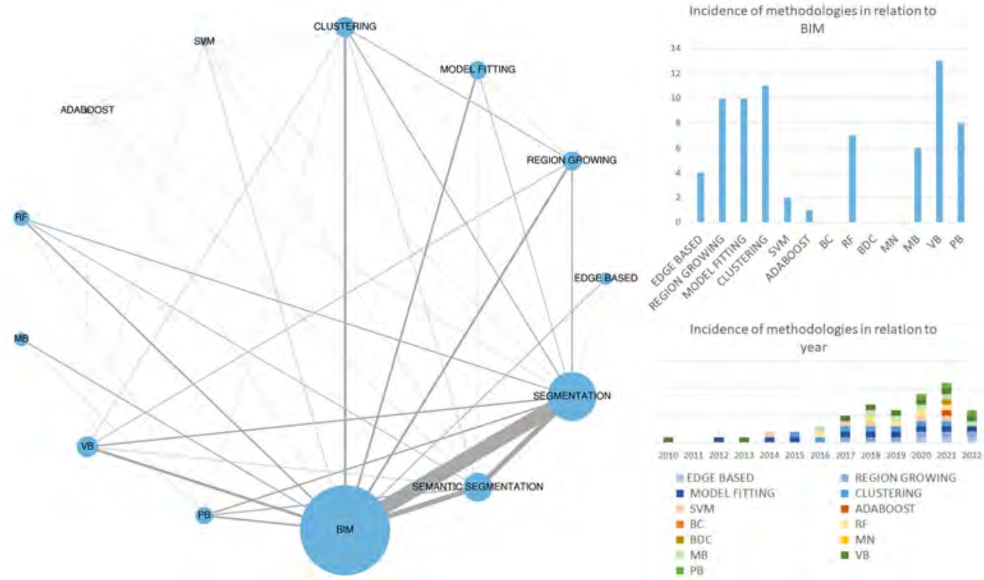

Fig. 6. Incidence of all analyzed techniques.

The use of voxels is not limited to semantic segmentation activities of point clouds through deep neural networks, so to avoid including articles using voxels in the search, but not for the purpose of semantic segmentation through deep neural networks, only articles with explicit reference to semantic segmentation are included.

Cited Studies

Referencing to EDGE BASED techniques, Chen, Kira, and Cho propose an approach for the classification of points belonging to point cloud based on the conversion of the cloud into its graph representation [Chen et al. 2019]. The classified points are then associated with an existing BIM model for deviance analysis between bim and built model.
In relation to REGION GROWING approach, Xiong presents a method for the automatic conversion of point clouds into digital information models, which involves the creation of planar surfaces from a voxelized version of the input cloud [Xiong et al. 2013]. The extraction of the surfaces takes place using region growing algorithms. The algorithm learns the features that distinguish the different types of surface and the relationships between them in order to classify the surfaces as belonging to walls, ceilings, floors. The recognized surfaces are further analyzed in order to recognize the openings present. The output of the algorithm is a model based on semantically classified surfaces, which is considered to be the basis for a subsequent work of generating a volumetric model to be exported in IFC format.
Regarding MODEL FITTING methodologies, Jung proposes a semi-automated methodology for the creation of BIM models, which provides for the automatic generation of CAD drawings starting from point clouds through the extraction of main planes representing walls, floors, ceilings, openings through RANSAC algorithm [Jung et al. 2014]. The CAD drawings thus obtained are imported into the BIM environment for manual modeling. Zhang proposes a method for the extraction of planar patches from point cloud using sparsity-inducing optimization based algorithm for the recognition of dependence between cloud points and through spectral clustering procedures for the recognition of linear dependence between the previously extracted segments [Zhang et al. 2015]. Model parameters of the extracted planes are derived using MLESAC and SVD while α-shape algorithm traces the contours of planar structures. Yang, Cheng and Wang propose a semi-automatic approach for modeling metal structures from point clouds [Yang et al. 2020]. The approach is based on the use of an algorithm that combines on PCA and cross-section fitting techniques to derive the position and direction of each circular metal structure present. Normal-based region growing algorithm and RANSAC algorithm are later used for modeling the connections between structural components.

Referencing to the approaches based on CLUSTERING techniques, Bassier and Vergauwen propose an approach to automatically group wall segments starting from point clouds using Conditional Random Field [Bassier, Vergauwen 2019]. Zeng, Chen and Cho propose a semi-automated method of detecting objects in point clouds that involves processing the cloud with pre-trained deep feature extractor in order to generate a 50-dimensional feature vector for each point [Zeng et al. 2020]. The resulting feature space is clustered using k-means clustering, while at the geometric level the space is clustered using region growing algorithms.
Regarding the SVM and ADABOOST techniques, Perez-Perez, Golparvar-Fard and El-Rayes propose a segmentation methodology of point clouds for generating BIM models [Perez-Perez et al. 2021]. Segmentation takes place using region growing algorithms while semantic and geometric label assignment takes place using SVM and ADABOOST classifiers respectively. The Conditional Random Field (CRF) method leverages the neighborhood context to increase accuracy in label assignment. The coherence between semantic and geometric labels is strengthened by Markov Random Field (MRF) in order to assign the final semantic label to each point.
In relation to RF techniques, Bassier, Van Genechten and Vergauwen propose a method for identifying elements present in point clouds for scan-to-BIM purposes [Bassier et al. 2019]. The methodology involves the use of a Random Forest classifier for the classification of floors, walls, beams, roofs and ceilings starting from a series of planar primitives obtained from the pre-segmentation of a point cloud. Classification is seen as preparatory to a subsequent development of class-specific reconstruction algorithms in order to create BIM objects. Croce proposes a semi-automatic approach for the reconstruction of BIM models starting from point clouds [Croce et al. 2021, pp. 145-152]. The approach consists of two main phases: the first phase consists of the semantic segmentation of the raw point cloud using Random Forest classifier. The segmented point cloud represents the input for the second phase, in which each class extracted via semantic segmentation is imported into BIM authoring software Autodesk Revit as a single point cloud. In the BIM environment, the RANSAC algorithm is used to deconstruct the cloud into a series of geometric primitives. If an object cannot be described using geometric primitives, a Revit family will be created. Croce proposes a similar method for the generation of 3D geometry to be integrated into BIM models starting from point clouds [Croce et al. 2021, p. 461]. The approach involves the semantic segmentation of the point cloud using Random Forest classifier and the generation of geometry through visual programming, through the use of the Rhinoceros Grasshopper plug-in.
Regarding the VB approaches, Babacan, Chen and Sohn 2017 propose an approach based on the voxelization of a point cloud in order to use convolutional neural networks for semantic segmentation [Babacan et al. 2017]. Deidda, Pala and Sanna 2020 develop a methodology based on the voxelization of a point cloud and the use of skeleton extraction algorithms for deriving a 3D graph of the structure [Deidda et al. 2020].
Referencing to the PB approaches, Pierdicca proposes a framework for the semantic segmentation of point clouds through Dynamic Graph Convolutional Neural Network (DGCNN), tested on the ArCH dataset [Pierdicca et al. 2020]. Matrone and Martini analyze the impact of fine-tuning and data augmentation techniques in increasing the performance of the modified DGCNN neural network, called DGCNN-Mod+3Dfeat [Matrone, Martini 2021]. In Lee, Park and Ryu's essay a graph-based hierarchical DGCNN (HGCNN) model is proposed for the semantic segmentation of railway bridges having electric poles [Lee et al. 2021]. In Yin's proposal a neural network model, ResPointNet++, is proposed for the semantic segmentation of point clouds for scan to BIM activities [Yin et al. 2021]. The proposed model is tested on a dataset of 4 industrial scenes labeled according to 5 semantic categories typical of structural and plumbing components.

Conclusions

Deep neural networks for scan to BIM activities are currently linked to the semantic segmentation of clouds. These methodologies, increasingly analyzed in recent years in reference to the BIM methodology, suffer from scarcity in the presence of data that a deep neural network needs for training. ArCH represents an example of a Dataset built for semantic segmentation activities related to Cultural Heritage. In order to make the use of deep neural networks more effective in this area, it is necessary to develop new public datasets related to construction activity. In the field of semantic segmentation, approaches based on Random Forest classifiers have obtained excellent results and are currently widely analyzed and used. Point cloud segmentation must be accompanied by geometry extraction processes for the translation of cloud segments into the corresponding BIM objects. In this perspective, techniques based on region growing and model fitting algorithms are particularly effective in the extraction of geometric primitives representing semantically segmented points. The approach consisting in the development of geometry reconstruction algorithms specific to each class of objects is also considered particularly effective. Referencing to BIM modeling, the reconstruction of geometry involves the extraction of the parameters necessary for the creation of a specific BIM object, as well as the relationships between these elements, and clustering of elements belonging to the same class according to common characteristics that allows to type these elements within the model.

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Semantic Mapping of Architectural Heritage via Artificial Intelligence and H-BIM

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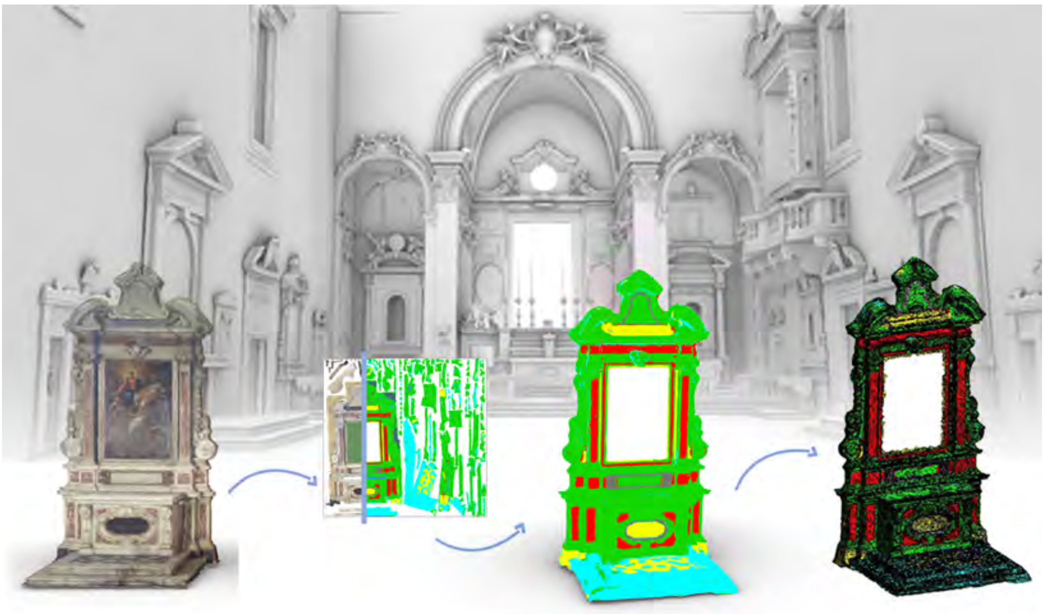
Marco Giorgio Bevilacqua

Abstract

Starting from the virtual photogrammetric 3D reconstruction, this work proposes a classification method, based on Artificial Intelligence, allowing to semi-automatically characterize the digital models of existing architectural heritage in terms of material mapping and/or decay condition. The obtained data, once classified, is used and transferred in BIM environment, so to favor the construction of informative models rich in analytical content. The proposed approach is described with reference to the significant case study of the Chiesa del Carmine in Pisa, for the study and restitution of the liturgical and decorative apparatus, as part of a large-scale research project, still underway, on the reconstruction of the tramezzo screens for the churches of the Mendicant orders.

Keywords
cultural heritage, classification, artificial intelligence, BIM, H-BIM, Chiesa del Carmine.



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Introduction

Nowadays, the digital documentation of architectural heritage necessarily requires the integration of different types of representation and the organization of information on different levels, for adequate restoration and conservation operations [Pamart et al. 2020]. Semantic segmentation techniques relying on Artificial Intelligence (AI) are emerging as privileged tools to appropriately organize, structure and classify the complex system of analytical and survey data related to an architectural object or site [Croce et al. 2021a].
In this paper, semi-automatic classification methods are exploited in order to associate the different semantic and descriptive information to the raw outputs of the three-dimensional survey, and Heritage-Building Information Modeling (H-BIM) systems are later considered to display and share the results. The case study on which the methodological approach is tested is the Chiesa del Carmine (Fig. 1), a church of the Mendicant order in Pisa (Italy): the classification is performed on the liturgical decorative apparatus of the church, and the textured meshes of the altars are analyzed so as to characterize the state of preservation of these objects, in particular with regard to the mapping of materials and decays [1][2][3].

State-of-the-Art

In the Cultural Heritage domain, an appropriate organization of unstructured 3D data derived from surveying is nowadays demanded. Classification techniques relying on geometry-based or texture-based approaches are emerging to semi-automatically organize, structure and interpret raw surveying information [Cera, Campi 2021], either characterizing the architectural object based on its geometric properties [Croce et al. 2021b] or on its colors or patterns [Grilli, Remondino 2019], respectively. Texture-based approaches, in detail, are demanded in cases where metric data alone are not sufficient to satisfy the tasks of description of a certain surface, e.g., if maps of degradation, surface alterations and materials are to be derived from the digital data. The Random Forest, a supervised Machine Learning algorithm, has been tested in [Matrone et al. 2020] as an effective method, applied on a case-by-case basis, for the automated classification of images, ortho-photos or UV maps starting from a suitable set of previously annotated

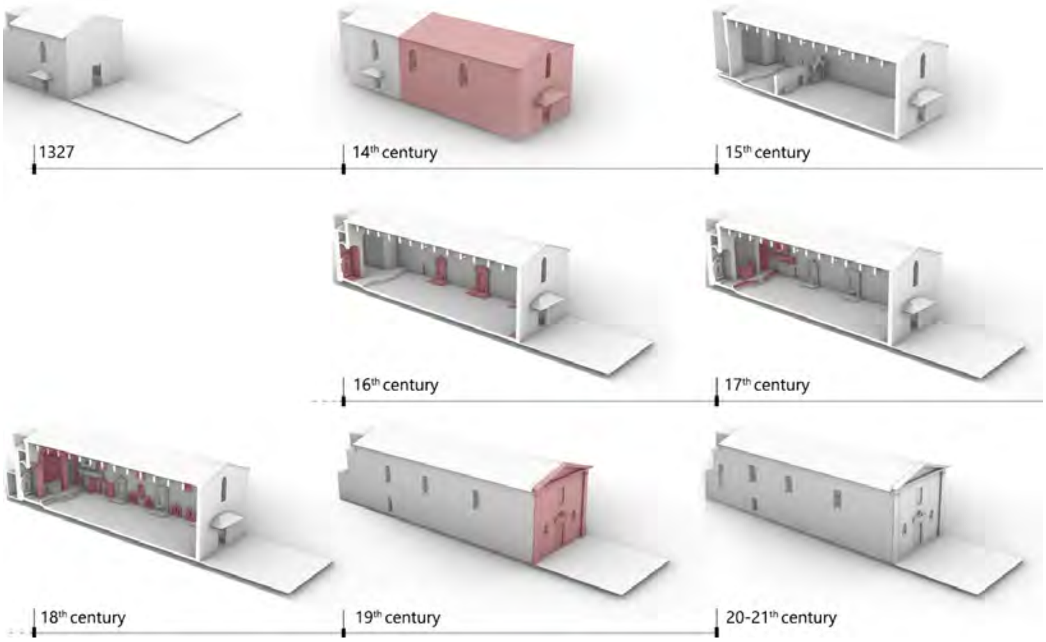

Fig. 1. Evolution of the Church over time.

data (training set). [Adamopoulos 2021] classified superficial damages on built cultural heritage even integrating multispectral data acquisition and supervised machine learning-based image segmentation, while [Murtiyoso et al. 2022] further investigated the use of semantic classification at the beginning of the classical photogrammetric workflow.
The classified digital data obtained can be leveraged in view of the construction of BIM-type information models for heritage objects [Croce et al. 2021], so facilitating the automatic identification of historical architectural elements and fostering the Scan-to-BIM process [Morbidoni et al. 2020].

The Church of Santa Maria del Carmine

The Church of Santa Maria del Carmine in Pisa was built by the Carmelitan monks in 1323, following their transfer within the urban walls of the city. Over the centuries, nationwide commissions have been involved in the construction and evolution of the church, so contributing to the achievement of its current architectural layout.
The church is composed of a single nave, covered by a gable roof. The enrichment of the internal decorative face dates back to the 17th century: along the side and back walls of the church, sumptuous baroque altars stand, placed on raised floors and closed by two columns, mounted on a base, which flank the altar table and conclude with a variously shaped crowning.

Fig. 2. 3D model of the Church's interiors, in the current layout.

Fig. 3. From left to right: Sparse point cloud; dense point cloud; mesh; textured model of the Altar of Santa Vittoria.

Fig. 4. Mesh models of some altars and decorative parts of the Church's interiors.

The analysis and study of the decorative liturgical apparatus of the church (Fig. 3) was part of the project of investigation on the location and arrangement of the 15th century *tramezzo* screen – i.e., the architectural partition typical of the churches of the Mendicant orders that transversally divided the church's nave, then removed following the Council of Trent (1545-1569) – inserted in a wider research work entitled "Seeing Below the Surface: Reconstructing Tramezzo Screens at San Francesco, Santa Caterina and Santa Maria del Carmine in Pisa" and conducted by a research group of the University of Pisa in collaboration with the University of Cambridge (UK), the University Suor Orsola Benincasa of Naples and the University of Padua.
Besides the work concerning the hypothetical reconstruction and the positioning of the *tramezzo* screen based on historical and archival information, the baroque altars of the Church were subject of an in-depth study on the mapping of decay and materials, which saw the application of most recent Artificial Intelligence and BIM modeling techniques.

Evolution of the Church Over Time

Undertaking a path aimed at deepening the knowledge of the artefact proved to be an essential support for the proposal of an integrated methodology that converged in the realization of a BIM Model, based on an initial laser scanner survey. A bibliographic and archival research first allowed to reconstruct the evolution of the church, as well as the changes and integrations of its decorative liturgical apparatus and architectural layout, over time.
For the construction of the study model displaying the temporal states of the church over the centuries (Fig. 1), perimetral walls, floor and roofs were preliminary traced over the original point cloud as BIM components, so to create the exterior building shell, in a Scan-to-BIM logic. Then, in order to virtually represent and describe the actual complexity of the liturgical apparatus of the church, the integration of reverse engineering techniques was considered: the altars and confessionals were segmented from the laser scanned point cloud, reconstructed as mesh models and later imported within the BIM platform Autodesk Revit (Fig. 4).

Study of the Liturgical Apparatus

A further, deeper level of analysis concerned the description of the liturgical apparatus of the Church: to this task, the integration with photogrammetric survey techniques was taken into account, so to better represent the radiometric (color) properties and decorative patterns of the Baroque altars and confessionals of the Church's interiors. For the latter, the results of photogrammetric 3D reconstruction technique were used to test the semi-automatic mapping of materials and decay conditions via AI (Fig. 5): in detail, the UV maps extracted from the textured mesh models were considered for the semantic segmentation task. On this bi-dimensional information, a supervised Machine Learning (ML) algorithm was applied in order to read, classify and return different degrees of degradation and/or types of materials of the altars.

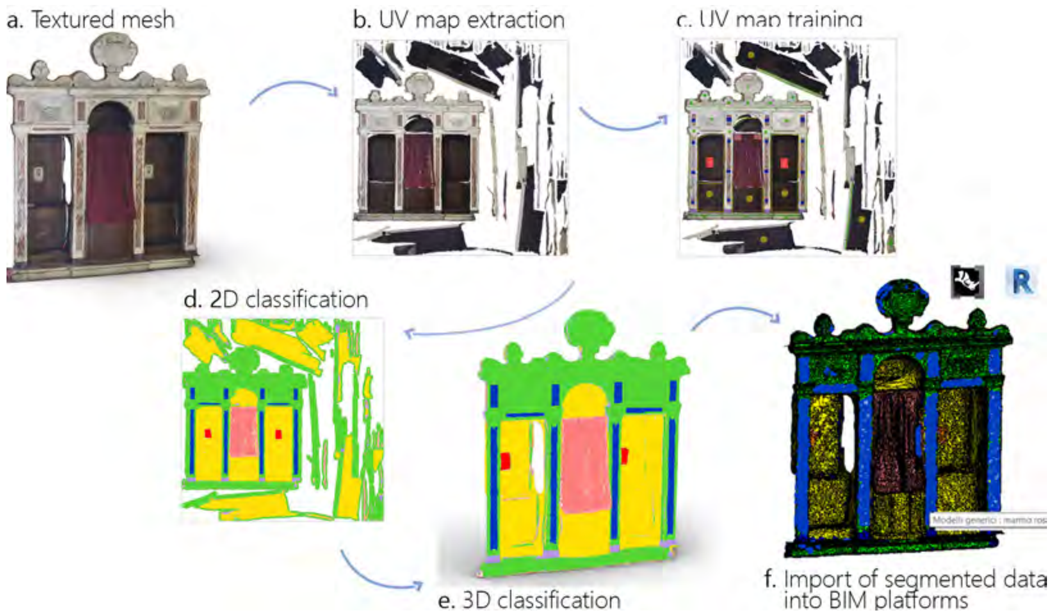

Fig. 5. Steps of the proposed methodology for the AI-based classification of the liturgical decorative apparatus.

The obtained distinction into classes of decay or types of material was preserved even at a final stage, when the classified mesh models derived from the segmentation process were inserted within specific H-BIM platforms, in a Scan-to-BIM application. To this end, portions of mesh having different material and degradation characteristics were imported into BIM platforms thanks to visual programming algorithms.

AI-Based Classification of Decay and Materials

A photogrammetric 3D model was obtained for the altars and confessionals composing the interior décor of the Church.

From the textured mesh of each surveyed object, and through the control of the seam lines, the UV maps were exported and later annotated in 2D to start the semantic segmentation process. The classes of materials or the levels of the degradation were identified and annotated over a reduced portion of data, to constitute a set of samples on which the ML model was trained. The training data was also supported by the so-called features, i.e., radiometric characteristics of data allowing the distinction between one class and another [Weinmann 2016].

A predictive model (Random Forest) is then trained on these data so as to foresee and map the classification of the entire dataset. As an example, the classes identified for Fig. 6 relate to the semantic mapping of materials. The paintings of the altar (the canvas material) are manually excluded from the classification, since trivial to segment over the UV map. Then, the different colors of the marble slabs (white, pink, yellow marble) are distinguished on a reduced training portion (Fig. 6b). Fig. 6c shows the segmentation results for the altar of Santa Vittoria, annotated based on the type of material.

At a final stage, the supervised classification obtained on the UV map can be projected back in 3D by exploiting the projective relationships between images and model, so to obtain an overall mesh model in which different colors correspond to different degrees of degradation or different types of material [Croce et al. 2022]. Class 6 – Background, related to the plaster of the side wall of the church, could even be used to support the appropriate selection of the mesh faces related to the altar, suitably excluding the faces related to the back wall.

The result obtained via this classification process is a classified datum, both available in 2D and in 3D, in which the portions of materials or the degraded surfaces are more directly recognizable, interpretable and computer-readable. The acquired information can be leveraged to enrich the digital representation with semantic data, related to material and decay mapping.

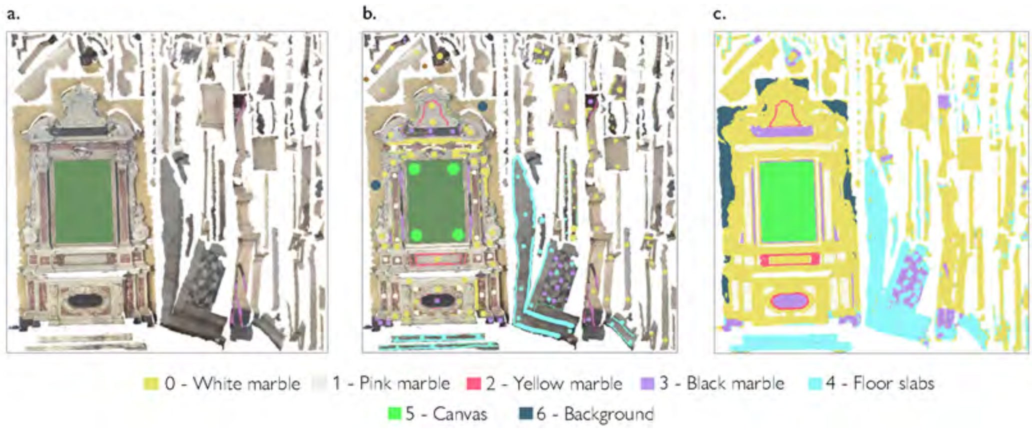

Fig. 6. Altar of Santa Vittoria: UV map (a), training set (b) and segmentation results (c) with related legend.

BIM-Based Reasoning on Material Mapping and Decay Conditions

By exploiting the projective relationships between texture and mesh, the classification information is transferred from the UV map to the 3D model. In a second phase of this work, we focus on ensuring that such a classification information is preserved even when importing the model of the altar or confessional into the BIM environment. To this task, a series of steps are considered relying on the use of McNeel Rhinoceros, Meshlab and Autodesk Revit software, provided as in Fig. 7 for the example of a confessional.

In detail, the classification information is used to duly segment each mesh model based on the color of its texture: in Rhinoceros environment, the color information deriving from the texture is appropriately transferred to the faces of the mesh, by evaluating the color at each texture coordinate (u,v). As such, the color information is transferred from the texture to each mesh face and becomes part of the geometry.

Then, through Meshlab, the initial mesh model is automatically segmented into sub-meshes on the basis of the color of the individual faces that compose it. In so doing, each sub-mesh corresponds to a single class of material or level of degradation, and can be imported singularly within the BIM environment.

To this latter task, the visual programming language Grasshopper, together with the Rhino.Inside.Revit plug-in, is exploited for a more direct connection with the BIM software Autodesk Revit. By a specific algorithm implemented through this plug-in, the architectural objects (sub-meshes) belonging to the single classes of elements are selected and associated to a specific Revit family (e.g., material or decay condition), so preserving their semantic description level (Fig. 8).

The graphical algorithm of Fig. 9, if replicated for each type of material present, thus imports within Revit portions of mesh that can be managed individually, obtained from a supervised classification and belonging to a same family / class.

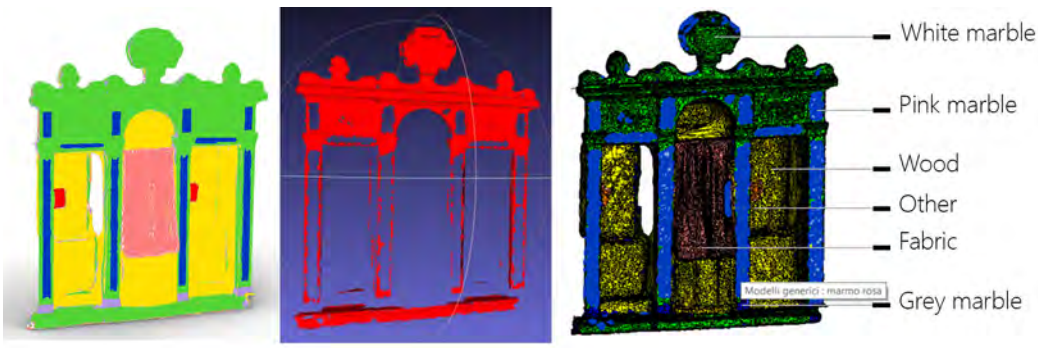

Fig. 7. From annotated data to H-BIM platforms. From left to right: classified mesh model; selection of the mesh relating to a single class; segmented classes visualized in Autodesk Revit.

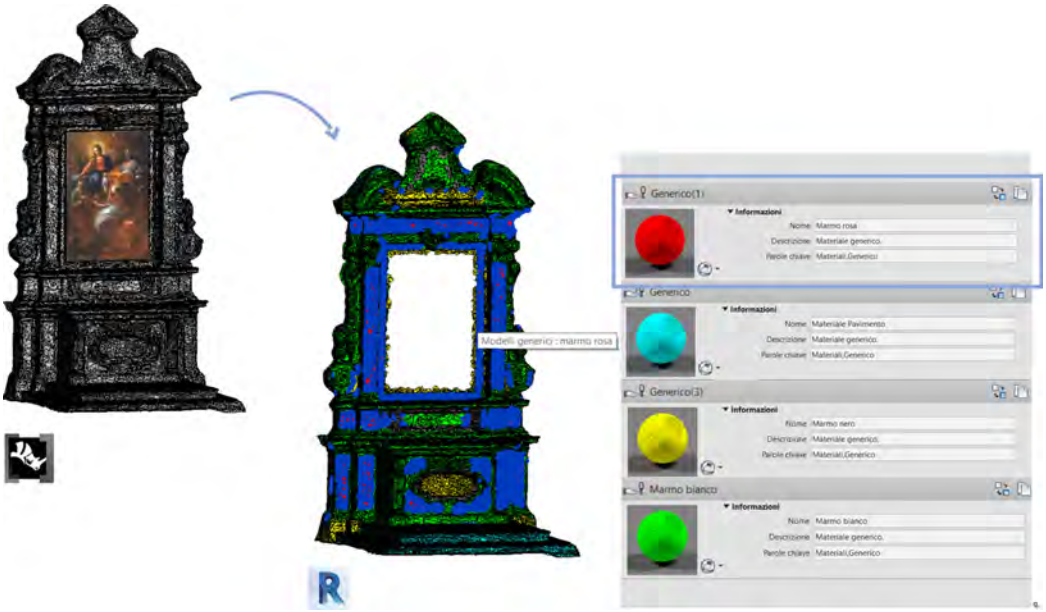

Fig. 8. The mesh is deconstructed according to the identified classes and the related materials are assigned in Autodesk Revit environment by visual scripting.

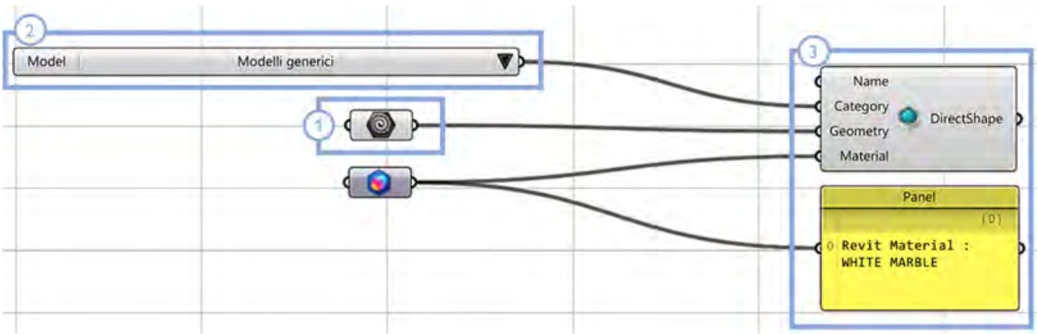

Fig. 9. Exemple of VPL import script via Rhino. Inside. Revit: the selected template geometry (1) is imported in Autodesk Revit as a generic model component (2), and it is associated the Revit Material 'White marble' (3).

In the more general logic of BIM information modelling, the semantic information resulting from the automatic segmentation is so transferred to a 3D information management and sharing environment, such as Autodesk Revit.

Conclusions

The digital representation of complex architectural elements, such as the decorative apparatuses of the churches of the Mendicant orders, may constitute a limitation for the construction of BIM systems for Cultural Heritage. In this context, the 3D model construction and implementation approach proposed in this paper is based on a semi-automatic modelling and classification strategy, exploiting AI and BIM environments. The skillful use of textured mesh models is fundamental in describing the state of surface degradation or the type of material of a certain architectural object, with a more automatic classification method. Therefore, importing single portions of mesh with different material or degradation characteristics into the Autodesk Revit environment guarantees the autonomous management and computerization of the parts composing the digital model. AI represents an extremely effective tool to support the recognition of some distinctive features of the objects, especially relating to the colorimetric and/or geometric nature of the parts. The supervised approach to the automatic classification reduces annotation times and fosters the conversion from survey data to H-BIM models.

As such, semantic data can be more easily shared, retrieved, visualized and stored over digital models, also in view of the use of the latter for augmented reality applications.
The results obtained in terms of description and semantic mapping of the model and of traceability and retrieval of information in H–BIM environment suggest the extension of the proposed methodological approach to the study of ornamental apparatuses related to other churches of the Carmelite order.

Notes

[1] This research is the result of the joint work of six authors. S.T. and V.C. developed the illustrated approach on AI and Scan-to-BIM and conducted the experimental works as part of the M.Sc. thesis by S.T..
V.C. wrote the original draft and prepared with S.T. the paragraph on the case study. G.C, A.P., M.M. and M.G.B. supervised the work and reviewed the paper. All authors shared the analysis of experiments and results.
The authors acknowledge Eng. Claudio Barandoni and Eng. Marco Simonetti for their valuable collaboration in this study.

[2] The work is part of the large-scale research project 'Seeing Below the Surface: Reconstructing Tramezzo Screens in the Mendicant Churches of Pisa', globally led by Donal Cooper (University of Cambridge, project leader), and locally coordinated by M.G. Bevilacqua and G. Caroti (University of Pisa), L. Repola (Suor Orsola Benincasa) and A. Giordano (University of Padua).

[3] A short video illustrating the contents of the paper is available at the following link: https://youtu.be/CBBd36AuKdc

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3DLAB SICILIA and UNESCO-VR. Models for Cultural Heritage

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Abstract

In the forecasts of 2019, the trend of the VR AR MR and AI sector was growing strongly; due to the pandemic events, real growth in the following two years has largely exceeded expectations. The possibility of interacting remotely by VR AR and MR modes during the pandemic was one of the solutions that made possible to overcome distances and barriers. As part of the *3DLAB Sicily* project financed by the Sicily region and aimed at enhancing the resources of the cultural heritage of the territory, the Department of Civil Engineering and Architecture of the University of Catania (DICAR) participates in developing VR, AR, MR by a research team pertaining to the disciplines of design and representation, for the study of some UNESCO sites. The acquisitions of the models have been started using active and passive sensors for various cultural heritage; the case studies range from protohistoric archeology to medieval military architecture to the Baroque of the Val di Noto. The aim of the project is the creation of 3D navigable models for VR and AR viewers, or for two and three-walled VR caves that have been built as part of the same project. Below are the procedures, considerations and evaluations for the first results obtained.

Keywords
VR, AR, 3D survey, archeological storytelling, 3D modeling.

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Introduction

In a historical moment of transition between material and immaterial, some reflections spontaneously arise, already raised by Tomas Maldonado [1] who mentions Kastler when he reminds us that, at the level of our senses, we are used to recognizing two key features in what we call objects: permanence and individuality [Maldonado 2015]. Recognition gives to the person certainties and confirmations. It remains to be understood why today is a widespread, and increasingly obsessive, craving for evanescent worlds, a feverish desire to project oneself, at least illusively, into the rarefied world of non-things [Maldonado 2015]. Several statements of Italo Calvino proposed in his invisible cities can be shared, when in the book-presentation he states that in invisible cities there are no recognizable cities [Calvino 2018], and later in chapter V: "Now I will tell how Octavia, the spider-web city, is made. There is a precipice between two steep mountains: the city is over the void, bound to the two crests with ropes and chains and catwalks. This is the foundation of the city: a net which serves as passage and as support. All the rest, instead of rising up, is hung below" [Calvino 2018], almost seems like a description of the fantastic scenario of a video game. The question therefore arises as to whether there is a search for science fiction or utopia. Utopia turns to a desirable or undesirable a possible-impossible, science fiction instead tells a desirable possible-impossible, and that's it [Maldonado 2015].
There remains the doubt to understand if there is a fascination for fantastic, utopian or real scenarios. On this issue, the evolution of film scenography has shown us a trend of screenplays that combine the three previous instances: scenarios that start from real places, or close to possible realities with fantastic or utopian insertions. But the real with insertions of any kind must be credible, so in the search for the "immersivity" of recognizable virtual places, the correspondence to the real takes on undeniable importance. In this sense, the geometric relationships, proportions, quality and detail take on an indispensable meaning. The part of the research that is shown focuses on transversal skills linked to representation in its connection with 3D modeling, to the survey of spaces that belonged to the past, looking for a usable quality result through the comparison between different mesh and texture elaborations, for of immersive peripherals. The three-dimensional spaces must be characterized by a correct proportion between the objects used to compose the scene, by a geometric but also historical reliability of the elements and by a recognisability of navigable places [Attademo 2021]. The definition of the detail can take on importance and meaning.
"Kublai Khan remains silent, reflecting. Then he adds: Why do you speak to me of the stones? It is only the arch that matters to me. Polo answers: Without stones there is no arch" [Calvino 2018].

Fig. 1. Cloud of points of Santa Maria la Vetere Church.

Fig. 2. Cloud of points of portic: Santa Maria la Vetere Church.

The 3DLAB Project – Sicily

Within the *3DLAB SICILY* project, the UNESCO VR work package deals with the development of VR and AR models of the cultural heritage (some of which are registered by UNESCO) of four municipalities that are partners in the project. The dataset of the use cases of the 3DLAB project crosses archaeological sites from different historical periods. We start from the Protohistoric period with the necropolis of Pantalica (SR) then we work on the Byzantine period with the military architectures including the Manfredonic Castle of Mussomeli (CL) and with the Castle of Vizzini (CT), that are also examples of religious architecture that have been strongly modified during a millennium. Then we focused on Cunziria, an example of industrial archeology of the eighteenth century, that was also a scenario for the famous novel *Cavalleria Rusticana* by Giovanni Verga and for the same theatrical transposition by Pietro Mascagni. The cultural contents of the use cases are very varied, representing topics for the development of augmented reality.

The Procedures

The data acquisition to develop the three-dimensional models has been carried out by 3D laser scanners, multi-image photogrammetry (SFM) with a full-frame digital camera, an Autel Evo Pro 2 drone, and a 3D Matterport Pro2 structured light camera.
The objectives of VR and AR were aimed at a uniform visual quality, where the differences of scales conjugated to the details, did not always allow to use a common workflow. Having already acquired scans with active sensors on a wide range of cases, we have focused on creating quality uniform 3D models, defined by meshes and textures. One of the major criticality has connected to the macro-clouds coming from different instruments: lidar, photographic cameras, drone and matterport. Also the big amount of data represent a criticality, because it is needed to balance quality of details with the easy "usability" of the model. The outputs of the project have two purposes: the first, based on lighter or simplified data, is the creation of VR and AI models starting from 3D models, the second, based on very detailed data, is intended to support research. Scanning data acquired for clouds combine the two paths although contents for research requires more detailed point clouds, as opposed to 3D models for VR and AI headsets. It is necessary to proceed with segmentations or decimations of the acquired data, continuously verifying the degree of visual definition in an iterative process. It should also be noted that some of the used software, during the merging phase of different models, in case of overcoming certain dimensions, automatically proceed to decimate the clouds, acting uniformly on the entire dataset of the cloud. This method cannot be accepted for archaeological models where even a single detail in the rock or stone element can have a particular value.

Also in the other cases analyzed, this procedure has limitations. The core of 3D modeling is the acquisition by 3D laser scanners, completed with SFM drone models for roofs and territory, and with digital terrestrial photos for mesh processing. Terrestrial laser scans were performed using reflective spheres with an overall average maximum error below 20 mm for models within 50 m. The models from the drone photos were set using a GPS-based flight plan, so the multi-image photogrammetric union (SFM) always provided accurate results. The SFM models from terrestrial photos have required continuous experimentation to arrive at a quality result. The next step was the union of the SFM terrestrial model with the drone model. Coming from different elaborations, the criticalities were represented by the search for a common software environment in which results from different file formats were manageable, without losing significant information such as color. The problem is well known: for example, the application Scene (Faro) allows excellent management of clouds both in quality and quantity but does not allow to combine and process clouds from other instruments. On the other hand, filters are automatically executed during exports operations, causing loss of characteristics and of quality of clouds. The right compromise was found in two software: Zephyr and Metashape. For the creation of VR models for standalone and smartphone viewers, the amount of data is an already known criticality, from which studies and researches for the segmentation of clouds have derived, that are still in evolution. There is a wide range of literature on the subject, with a wide range of typological cases in archeology and historical architecture. The recent works are always valid as a reference: *Semantic segmentation of the point cloud using a deep learning framework for cultural heritage* [Pierdicca et al. 2020], but other works have also shown the complexity of the problem [2], that is more important for very detailed architectures such as religious.
The visual result linked to the quality of the details in virtual reality therefore conflicts with the amount of data. Automatic procedures do not solve the problem of the different concentration of points in the areas with more details [3]. The problem for the CAVE is different.

Fig. 3. Cloud of points of Santissimo Crocifisso Calvario Church.

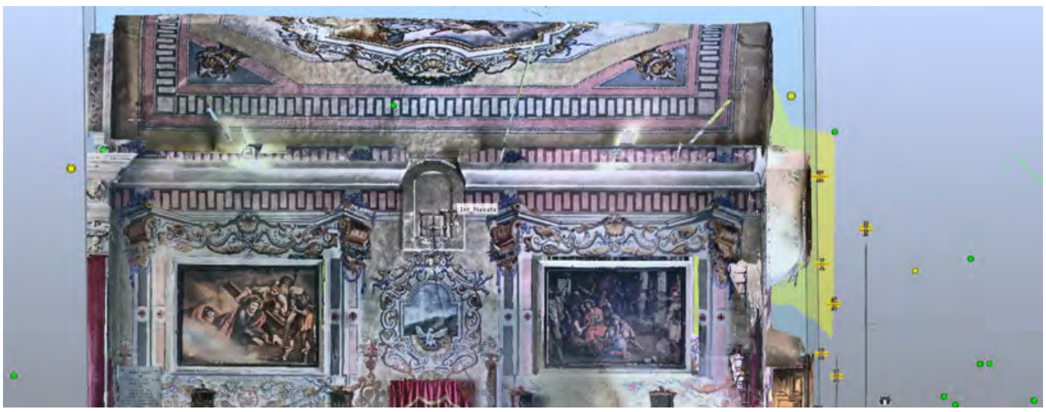

Fig. 4. Cloud of points of the inside: S. Crocifisso Calvario Church.

Because there is not an unique and simple solution for each model, we analyze single samples, proceeding by parts, separating the constituent elements of the various architectures and evaluating the results. The following elements were therefore identified: wall surfaces, vaulted surfaces, arches, portals, columns, etc. Then, we proceeded with the decimation and subsequent processing of 3D models of individual elements using the most popular software for mesh and texture, and then reassembling a single model as a sum of the individual processing.

Data acquisition by active and passive sensors:

- LiDAR system – Faro Focus S plus 350 3D laser scanner
- 3D structured light scanner system – Matterport
- Multi-image photogrammetry (SFM) – Canon EOS Mark III Full Frame Digital Camera
- Drone – Autel

The post-processing and merging phase of the clouds by:

- FARO SCENE software for point clouds
- Matterport Cloud for Matterport camera acquisitions
- Zephyr from 3Dflow and Metashape from Agisoft for SFM models

The Mesh and Texture phase:

- SW FARO SCENE for the union
- SW Meshlab for meshes
- SW Cloud Compare for meshes
- SW Zephyr – mesh and texture

Critical issues:
Using automatic software procedures does not allow to obtain an acceptable mesh and texture processing, in which it is possible to appreciate the high level of surveyed details stored in the data:
- rock sites have irregularities due to the roughness of the walls that cannot be managed with an overall elaboration;
- military and religious architectures present a very large amount of data that cannot be managed as a unit:

- the castle of Mussomeli: 105 scans for the internal courtyard and the covered areas;
- the castle of Vizzini – once Bourbon prison, 95 scans;
- the church of Santa Maria La Vetere 9 internal scans, 33 external;
- the church of the Crucifix of Calvary 12 external scans, 8 internal.

For the church of the Crucifix of Calvary the E57 file processed with the texture has a size of 13 Gb, for the church of Santa Maria La Vetere the number of polygons have been reduced, obtaining a size of 2 Gb. Currently we are looking for an optimal solution between the visual quality of the models and the fluidity of the scene, evaluating different options, including loading only one environment at a time. In parallel, the results of Matterport Pro2 are being evaluated, which involves a size of 30 Mb for each station.

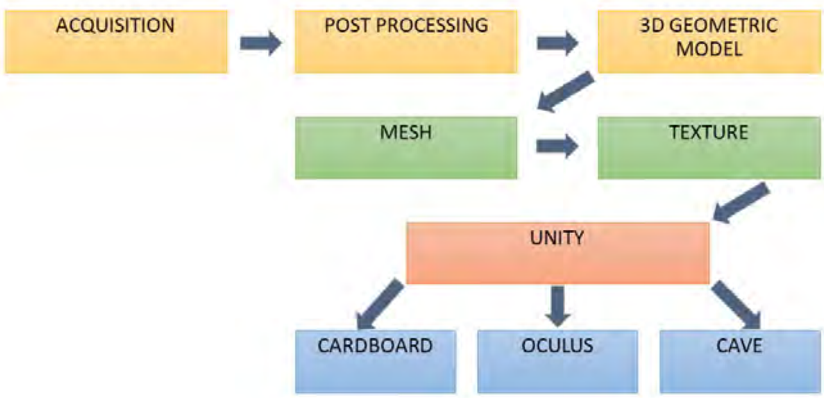

Fig. 5. Pipeline.

Immersive Models

After the creation of the 3D model, the result was verified using the applications for the Virtual Reality devices and the VR CAVE. The most used software are Unity3D and Unreal Engine 4. It should be noted that to develop VR, the software Unity3D allows a better interaction to manage the "assets", that are virtual objects representing a real or imaginary world. The compatibility of the Unreal Engine's platform is limited compared to Unity3D, so we preferred to use it: no wonder that Unity has a market 3 times higher than Unreal Engine (30,000 vs 10,000). We will show below the development phases that led to the creation of an application, compatible with Smartphones (combined with Cardboard), with Oculus Quest2 and with VR-CAVE, which allow the user to visit the object of the application.

Smartphone with Cardboard

For the development of applications aimed at smartphones, the software Unity3D 2020.3.x version was used together with some plugins needed to simplify the whole process: XR-Plugin Management and Cardboard XR. The first was used to manage, load and initialize the extended reality. The second plugin, Cardboard XR Plugin, allows the management and creation of a stereoscopic VR system for Google Cardboard. It supports basic VR features like motion tracking and stereoscopic rendering which make it easy to create the user interface. The difference in scale between the confined environment of the VR-CAVE and the reproduction of the real environment, as well as movements of users within the virtual environment, has been managed by the implementation of "trigger points". The triggers are placed in different points in the VR space and are used to teleport users to different areas. If the user looks at one of the trigger points (for example a point on the floor) for a preset time interval, the user's position will be translated near to that point.
The optimization of the different elements involved in the immersive experience was managed. Lights have been pre-calculated and shadows have been managed in order to make it possible to use the application even by smartphones with limited computational capabilities, allowing a fluid experience. About the computational complexity of the system, it is known that it depends by the resolution of textures. Choosing the correct resolution provides optimal and fluid navigation of the model, but it is needed also to maintain a realistic visual experience thanks to a good level of detail. Providing a high-level experience prevents users from VR sickness or Cybersickness, that are the sensations of dizziness, disorientation or malaise caused by the delay in latency. This delay can produce a dissonance between body

Fig. 6. Application for Oculus.

movements and actions in the virtual environment, generating a sense of disorientation. More generally, a conflict between the signals transmitted by the different sensory systems and their inconsistency with respect to the central nervous system creates perceptual difficulties: therefore the quality of the model is undeniable.

Oculus Quest2

To develop VR applications for headsets, such as the Oculus Quest2, Unity3D provides several plugins. The Oculus XR plug-in was used to include motion control functions; XR Interaction Toolkit for user interface management and XRPlugin Management was used to create and manage the XR plugin. These plugins help to control the user's movements within the VR environment and manage interactions with other objects.

CAVE

The development of the VR application for the CAVE was organized for a 3-wall CAVE, consisting of a front wall, and two side walls. Taking advantage of the Unity3D 2019.4.x version, the Mirror library was used for the management and synchronization of two workstations. The first workstation is dedicated to managing the front wall, while the second manages the other two. The network components allow to synchronize the player's position and the virtual objects in the CAVE. The UVRPN plug-in was used to manage the controls and the user's position in the CAVE in real time. This simplifies the management of tracking data sent from weared devices and acquired by VRPN technology. Therefore, the user can move around, while the virtual environment can be processed and organized in real time, in compliance with the actions traced. About the optimization of models, using dedicated hardware allows to choose higher resolution of the texture of the 3D model than the resolution used for Oculus and Smartphones. In this case, the rendering of lights and shadows is calculated in real time [4].

Conclusion

The 3DLab-Sicilia project funded by the region aims to create a regional network for the provision of innovative services based on advanced visualization technologies through virtual reality for archaeological sites and museums. The results in progress are visible on the project

Fig. 7. VR CAVE

website [5]. This article gives the results obtained in the first year of activity for two churches. The pipeline presented here was used for the development of the VR models of the church of Santa Maria La Vetere and of Calvario located in the municipality of Militello val di Catania (CT). Three software environment (for smartphones, oculus quest 2, VR Cave) has been used, in order to guarantee full access to every kind of users, but with different qualities in terms of results. Among these, the oculus quest 2 viewer constitutes the right compromise and offers the most engaging effect, due to the specific nature of the device. The VR Cave represents the optimal result, but remains confined to the location of the Cave. The Card\ board for smartphones is an efficient alternative at low cost but with a lower quality. The 3DLAB project still in progress, based on the development of continuously and rapidly expanding technologies, aims to optimize results for future applications.

Acknowledgements

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Notes

[1] Maldonado Tomas (2015). *Reale* e *Virtuale*. Milano: Feltrinelli.

[2] Matrone Francesca, Lingua Andrea Maria (2021). *Tecniche di deep learning per la segmentazione semantica di nuvole di punti del patrimonio architettonico*.

[3] Griffiths David, Boehm Jan (2019). *Una rassegna sulle tecniche di deep learning per la classificazione dei dati rilevati in 3D*.

[4] Barbera Roberto, Condorelli Francesca, Di Gregorio Giuseppe, Di Piazza Giuseppe, Farella Mariella, Lo Bosco Giosuè, Megvinov Andrey, Pirrone Daniele, Schicchi Daniele, Zora Antonino (2022). A Pipeline for the Implementation of Immersive Experience in Cultural Heritage Sites in Sicily.

[5] The works in progress of the 3Dlab-Sicily project are available on the website: https://www.3dlab-sicilia.it/it_it/

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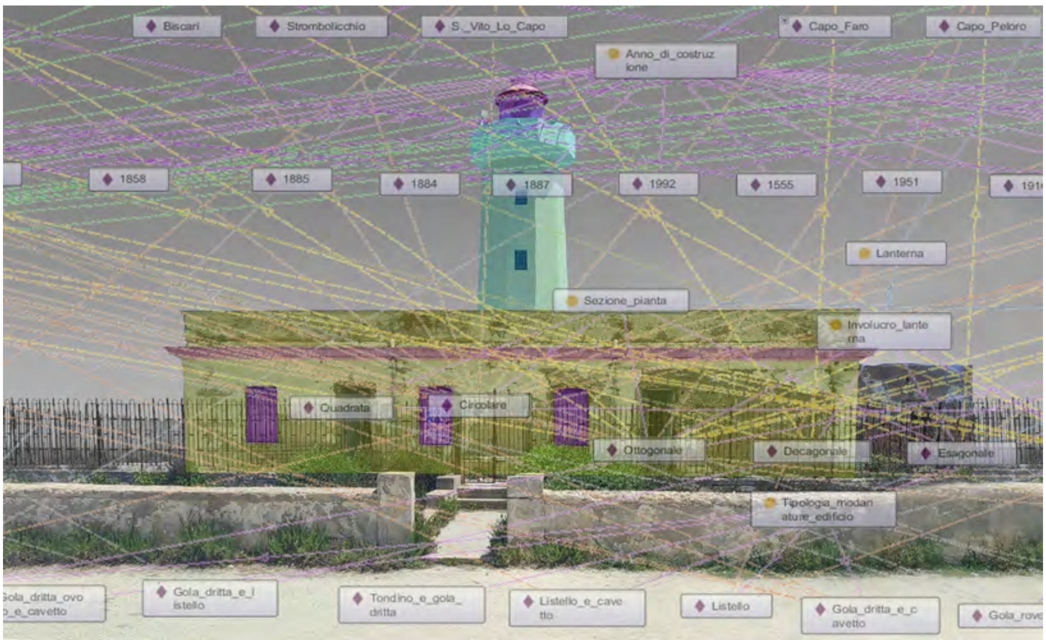
Connection & Knowledge: from AR to AI. The Case of Sicilian Lighthouses

Sonia Mollica

Abstract

The development of ever new and innovative technologies is now able to significantly enrich the numerous possibilities in the field of research, use, enhancement and understanding of the existing cultural heritage. In this sense, the initiatives in the field of augmented reality and artificial intelligence appear to be a possible asset through which to undertake connection and mixing networks between the intrinsic and extrinsic data that characterize buildings. The use of semantic and ontological data – that is fields based on an increasingly solid interoperability and exchange of data – make it possible to develop a mutual knowledge in a relationship of connection between territory and architecture. This contribution, therefore, investigates the possible application of augmented reality and artificial intelligence in the context of Sicilian lighthouses, or a heritage characterized by well-defined architectural and landscape components.

Keywords
knowledge, connection, sicilian lighthouses, semantics, ontology.



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Introduction. Technology, Semantics and Lighthouses

Scientific progress in the field of augmented reality, artificial intelligence and virtual reality are today applications to which numerous fields of research and studies are addressed, in order to ensure an increasingly effective enhancement and dissemination of cultural heritage [De Paolis 2012]. Augmented reality applied to cultural heritage allows a more in-depth view of architecture, also usable at a distance, through which to discover new formal and compositional connections. In the context of augmented reality, the semanticization of cultural heritage can represent a strategy for a simpler reinterpretation of the artefact in both intellectual and virtual terms, to be implemented through visual expedients such as projections and cognitive maps, in order to highlight relationships and compositional determinants [Croce et al. 2020].
Nowadays the mix of knowledge and disciplines through which to obtain ever more in-depth and interactive levels of knowledge of the artefact becomes increasingly fundamental. If on the one hand augmented reality is configured as a tool suitable for an increasingly immersive use of cultural heritage, it needs a new interpretation and to be combined with new directions: this is the case of artificial intelligence, or a discipline addressed to the reasoning of the intelligent system to which numerous addresses and fields of study are approached. In general, research based on "intelligent" behaviors is carried out by breaking down into sub-problems – an action therefore common to the semantization of the object in interconnected systems – including the ontological method [Grasso 2012]. It is in the context of augmented reality and ontology that the landmark architectures of each coastline are inserted, a guiding address for sailors and protagonist of suggestive stories: lighthouses. These types of architectures, in fact, are characterized by well-defined and common compositional groups and sub-groups for the different lighthouses located in the territory. The use of semantics applied to lighthouses – in this contribution located in Sicily – makes it possible to develop applications in the field of augmented reality, through which to view unpublished knowledge, and of ontology, thanks to which to frame existing but also new connections cognitive.
In the field of semantics applied to lighthouses, in fact, it is possible to significantly distinguish those that are configured as the fundamental characteristics of the main structure. The lighthouse building, the tower and the lantern represent the three basic macro groups that enclose the formal features of the building. They convey the individual and decorative elements of the building – moldings, ashlar, compositional types, etc. – that is, common characteristics that can be traced in certain geographic locations or in specific architectural cultures. It is precisely these characteristics that make up a subgroup of the semantic apparatus, making the classification of the lighthouses an inverted pyramid decomposition in which the starting point is represented by the total and the arrival point are the small parts that make up the building. It should be emphasized that semanticization by parts is not understood as an alienation of the elements in view of self-sufficient objects, but rather as a detailed study of the same aimed at understanding the relationships and recurring characteristics [1] [Zerbetto 1998]. By using augmented reality combined with ontological maps, we want to hypothesize the creation of an application capable of combining these two sciences towards a single interface through which historical, architectural and cultural characteristics can be viewed in real time.

Semantics and Augmented Reality at the Service of Knowledge

As is well known, the learning of knowledge can take place effectively through the transposition of knowledge on analog-digital representations, all aimed at safeguarding and forming a society linked to the memory and historicity of places [Bortolotti et al. 2008]. These technologies, profoundly pervasive, enhance and modify the conception of space, expanding the real experience through increasingly immersive virtual spaces, that is, as Myron Krueger intended them, spaces so immersive as to seem real, in a dense human-machine relationship [Krueger 1985]. Although the use of mixed reality is configured as a tool with an innovative capacity – allowing us to position digital objects in the physical world, or even be ourselves present in both the physical and digital world – in this discussion also reality augmented, it is

capable of enriching human sensory perception through cognitive information derived from ontological knowledge.
As previously mentioned, the protagonists of this discussion are the Sicilian lighthouses, that is, architectures that welcome, in addition to a vast history and material and immaterial tradition, an identity and defined architectural composition. In this sense, in fact, the lighthouses, in addition to their intrinsic geometric characteristics, can be distinguished and classified through a formal and compositional cataloging of the building organism in recurring structures. The main structure of the lighthouse can therefore be broken down into three main volumes: the building [2], the tower and the lantern, which are elements that, with the exception of the building, we find in every single coastal architecture [3]. The previous volumetric identities can be distinguished in several semantic-structural classifications, among which we recall: the one-level, two-level or three-level block for the building component; the tower with a square, circular, octagonal or mixed plan for the tower; the lantern with an octagonal, decagonal, dodecagonal plan. The individual decorative elements and openings of the architecture are conveyed in them – moldings, ashlar, shelves, square openings, circular openings, etc. – capable of characterizing the building while representing an element common to other buildings of the same type (Fig. 1).
Net of a semantic classification applied to all cases of Sicilian lighthouses, it is possible to hypothesize the transposition of the same data through the creation of intuitive applications, using the technology/methodology of AR and VR. On the one hand, by positioning beacons near a defined lighthouse, it is possible to access an augmented reality interface, on the other hand, the use of viewers, regardless of where you are, makes it possible to use a digital space of lighthouses, addressed in both cases to knowledge. In particular, virtual reality allows access to the three-dimensional model through the personification of the user according to an avatar, through which it is possible to rotate the model, observe the details from every angle

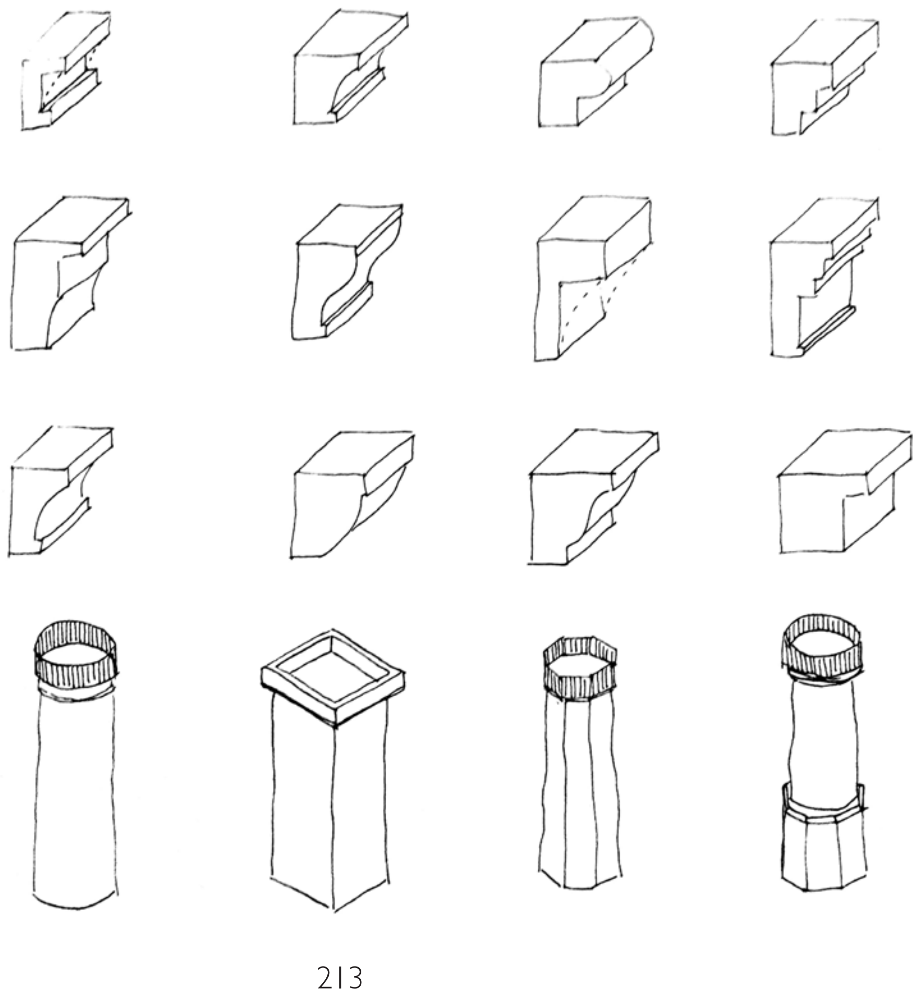

Fig. 1. Recurring semantics.

and at the same time view the semantic characterizations identified by the different colors of the model. Wearing a common VR viewer it is therefore possible to immerse yourself in an interactive knowledge space through which to view not only the architecture, arranged according to geographical location, but also to know its semantics and history (Fig. 2). At the same time, through the augmented reality application it is possible to access the same semantic classifications of the building using only the smartphone, being able to view the same identified by the colors by directing the camera of the digital instrument towards the existing architecture (Fig. 3). The interactive application allows you to select the single semantic classification in order to be connected to the ontological structure loaded into the system, subject of the next chapter, making the cultural experience increasingly aware and interesting towards users, also ensuring the usability of the data not only to an expert audience.
As regards the uses, therefore, this applicative hypothesis appears to be addressed exclusively for tourism purposes, for knowledge and dissemination of the heritage of lighthouses, as it is based on a level of knowledge of the architectures that is not deep enough to define an operational tool aimed at maintenance and restorations, even if it can constitute a solid basis.

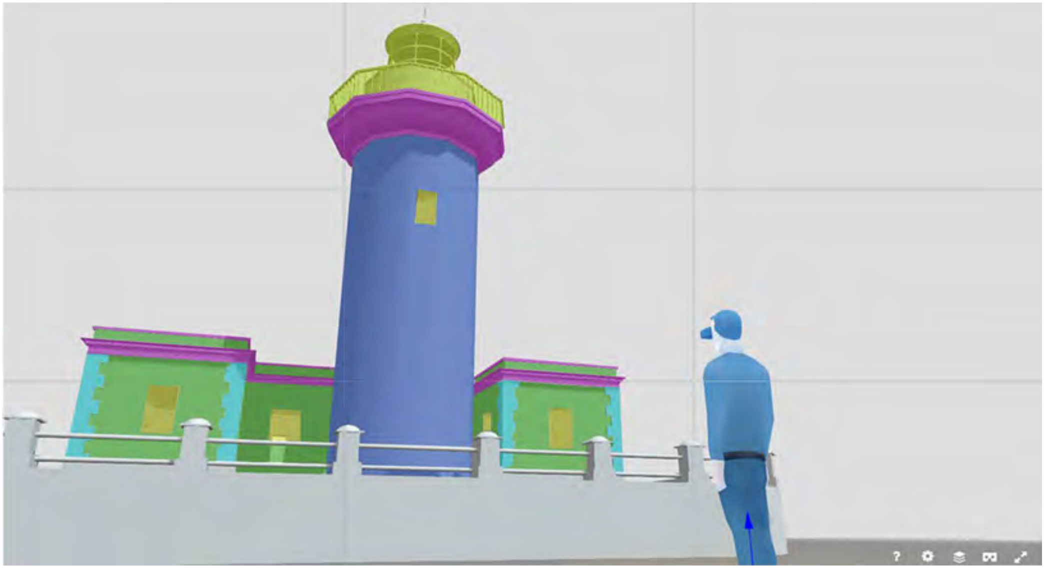

Fig. 2. Virtual Reality applied to lighthouses: semantics and fruition.

Fig. 3. Between Augmented Reality and semantics: connections of knowledge.

Finally, it should be emphasized that, if on the one hand the collection of data and semantics is configured as an action already in place, on the other hand, the development of this application is still in the creation phase.

Artificial Intelligence: Ontologies and Maps of Knowledge

There are several definitions of ontology: from a philosophical point of view it is a "systematic explanation of being"; from the computer science point of view we recall that of Gruber who defines it as an "explicit specification of a conceptualization" [Gruber 1995]; Borst defines it as "a formal specification of a shared conceptualization" [Borst 1997] while according to Guarino "it defines a logical theory that gives an explicit and partial justification of a conceptualization" [Guarino 2000]. But the definition that best matches the content of this contribution is undoubtedly the one asserted by Swartout in 1996: "an ontology is a structured set of terms that describe a domain and which can be used as a skeleton for the creation of a knowledge base" [Swartout 1996]. At an operational level, in fact, ontology represents a shared conceptualization of a certain domain and is based on the definition of the concepts and relationships that characterize the knowledge of the chosen domain, making it possible on the one hand to intelligently organize already known information, and on the other hand to establish new deducible assertions, or new knowledge [4].
Formal ontology, entered by law in the field of artificial intelligence and the representation of knowledge, is configured as a first-order theory that can be divided into two well-defined parts: syntax and semantics. If in augmented reality semantics is treated as an expedient for analysis, in ontology it takes on deeper meanings, capable of putting all data into a dense interoperable relationship through a domain. But why is ontology configured as the perfect method for cataloging the semantics of cultural heritage? This is because, in fact, ontology improves the management/understanding and access to the complexity of data, as well as improving its implementation and interoperability, in which semantics is configured as the most effective cataloging tool [Acierno et al. 2017].
There are different models for the organization of information in ontology, but to better represent the data and describe the type of relationship that binds the elements, it is necessary to understand what an ontology is and the use of specific terminologies (Fig. 4) for the domain we want to refer to. This is because the different terms can have multiple meanings, based on the field of study, and also because the definition of a specific terminology makes it possible to link the ontology and other IT and enhancement processes [5]. The first step to be faced in creating an ontology is defining the goal based on the data and therefore defining the questions to which you want to give an answer. The data is collected and analyzed in order to meet the intended objective, with subsequent cleaning of the data. Net of an optimal data collection, we proceed with the creation of the

Term	Definition	Source
Lighthouse	Light signaling instrument, consisting of a projector of white or red or green light, with a range of 10 to 40 miles, usually implanted in a solid tower construction or in another suitable building, on the most visible points of the coast (ends of the piers, promontories rocks), to serve as a fixed point of reference for night navigation. it is said characteristic of a f. the type of light emission (continuous or intermittent) and its range. In some cases it is mounted on a float (light boat, light ship). [...]	Treccani dictionary Url https://www.treccani.it/vocabolario/faro/
Nominal range of the light source	The range of the headlights can be divided into nominal, geographical and luminous range. The nominal range, on the other hand, is independent of atmospheric conditions and is defined as the light range that the lighthouse would have under standard conditions, with a meteorological visibility of at least 10 miles. The nominal range of a lighthouse is from 10 miles to 40 miles.	Sites specialized in boating; lessons for the acquisition of a nautical license. Url: https://www.nauticando.net/lezioni-di-nautica/segnalamenti-ottici-marittimi/; https://www.mkonsulting.it/joomla/images/Navigazione/fari%20e%20segnali%20da%20nebbia.pdf.
Lantern	Part of the architectural complex of the lighthouse, the lantern is the glass structure that contains and protects the lamp and the optics. Generally circular in shape, but also polygonal, the lantern is made with special technical devices to be as transparent as possible to the light signal emitted by the optic [...]. Finally, on the tower there are one or more hanging galleries (the "terrace" or "gallery"), outside the service room and the lantern, the latter mainly to allow cleaning of the external surface of the lantern windows.	Sites specialized in boating and officers. Url: https://www.nps.gov/maritime/; https://www.mkonsulting.it/joomla/images/Navigazione/fari%20e%20segnali%20da%20nebbia.pdf. Libro: L'architettura dei fari italiani

Fig. 4. Ontological terminologies.

semantic model and its transposition into OWL. In order to optimize the usability of the created ontology, it is possible to create an interface that contains it in which to report the "competency question", or the questions that we can answer with our ontology.
To better clarify the practical creation and theoretical existence of an ontology, we want to emphasize that there are three main elements in it: the classes that represent the general concepts of the domain; the properties that define the type of relationships that exist between the classes; the instances representing real world objects that are part of a given class (Fig. 5). In the ontology of Sicilian lighthouses, the creation of classes and dominion are placed side by side with the semantic decomposition previously exposed: building, tower, lantern. For each class, therefore, the instances that make up the classes and subclasses are associated, explaining what are the individual decorative components and the openings of the architecture belonging to the three macrogroups. Associated the instances with the semantics, it is possible to define the object relationships, or the object properties, in the "individuals" section, through which it is possible to record all the relationships between the identities that make up each specific lighthouse. Net of the creation of an ontology of Sicilian lighthouses, it is possible to generate the "knowledge graph", that is the representation of the entities of the real world according to their relationships organized by means of a graph with nodes, through which it is possible to highlight classes and relationships. The graphic data can be used according to two interpretations: focusing the interest on the single lighthouse (Fig. 6) or deriving the knowledge starting from the semantic clusters up to the architectures associated with certain semantic characteristics (Fig. 7).

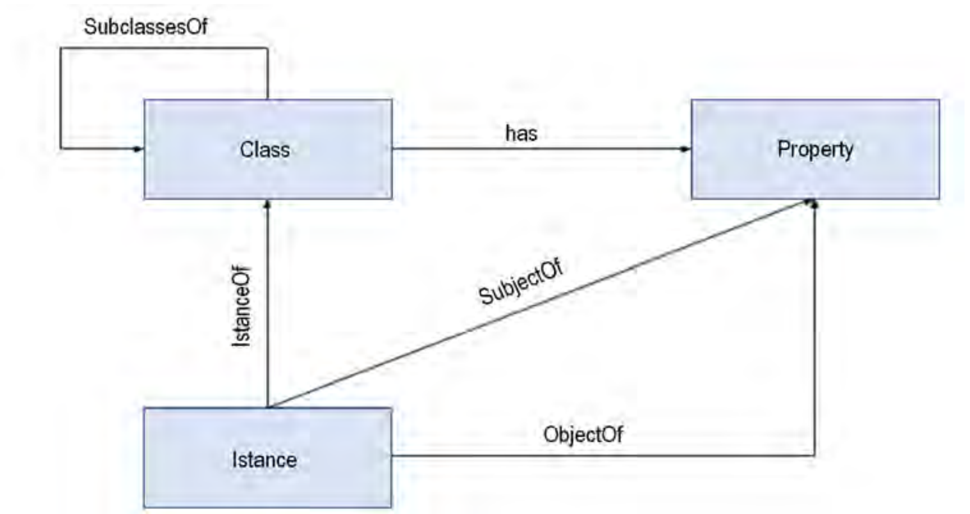

Fig. 5. Relationships: classes, instances and connections.

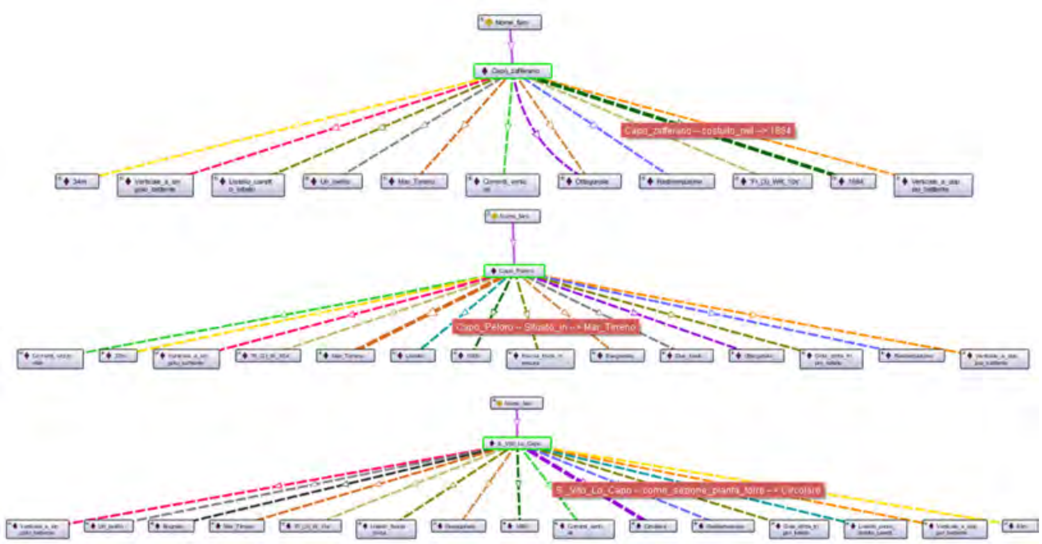

Fig. 6. The ontology of lighthouses: bottom-up approach.

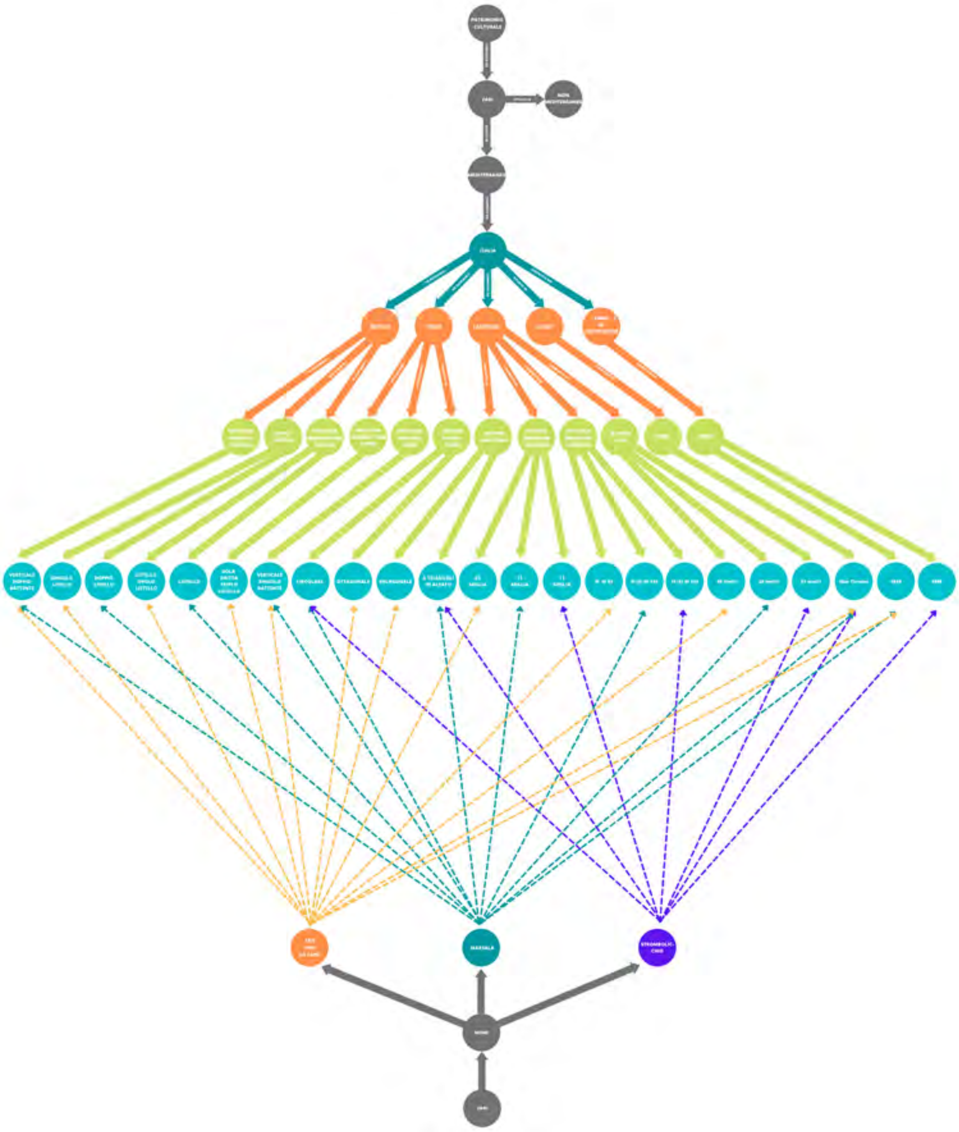

Fig. 7. The ontology of lighthouses: top-down approach.

Conclusions: Augmented Reality, Ontology and Reproducibility

If in augmented reality semantics is treated as an expedient for analysis, in ontology it takes on deeper meanings, capable of putting all data into a dense interoperable relationship through a domain. The use of open source software makes it possible to connect – through the creation of object properties, data properties and classifications – of the etymologies and common identification systems of the different elements of the building that are to be taken into consideration, creating not only an intelligent and interactive system of connections but also a process of deep knowledge of the building. In this sense, the contamination of ontological sciences in augmented reality applications makes it possible to manage both visual semantic data and the "competency question", useful for understanding and knowing the connections between the building and the rest of the architectures present in the domain. To validate the potential of the use of ontological sciences there is the possibility of – in addition to intelligently organizing the information already known – to establish new deducible assertions, or new knowledge, useful for making the interface always modifiable and integrable with further data, establishing a process of in-depth knowledge of the building and its relationship with similar architectural structures.
Ultimately, the ontological and semantic methodology makes it possible to reproduce the process as the semantic classification is often applicable to all that cultural heritage including peculiar and

recurring compositional characteristics, as in the case of lighthouses. In addition, ontological sciences today represent researches aimed mostly at an audience of specialists who, associated with an augmented reality interface, can be used through a simple application on a smartphone to be used on site or remotely, in line with those that are the cultural development guidelines based on edutainment [McLuhan 1964].

Notes

[1] As the Gestalt maintains, "Knowledge cannot be broken down into simple elements. The whole is more than the sum of the single parts", that is, the totality of the perceived is defined not by the sum of the single parts but by the sensory activations that arouse the single parts side by side, in a complex totality [Zerbetto 1998].

[2] In this discussion, the term "building" means the structure in which the lighthouse's residence and/or office is located and not the totality of the architectural structure.

[3] By lighthouses we mean those architectures that include a masonry structure, thus not considering lighthouses with a metal structure.

[4] In the case of the ontology of Sicilian lighthouses, the data already known are inherent to the year of construction, the type of light emission, although these data are still not always easily friable. On the other hand, all that concerns the semantics of the lighthouse is part of the increase in knowledge, that is, the decomposition of the individual parts of the building through the study of recurring languages.

[5] In this sense, in fact, the use of specific terminologies makes it possible to connect computer knowledge with different digital environments such as, for example, parametric modeling, to be connected using element IDs.

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Image Segmentation Procedure for Mapping Spatial Quality of Slow Routes

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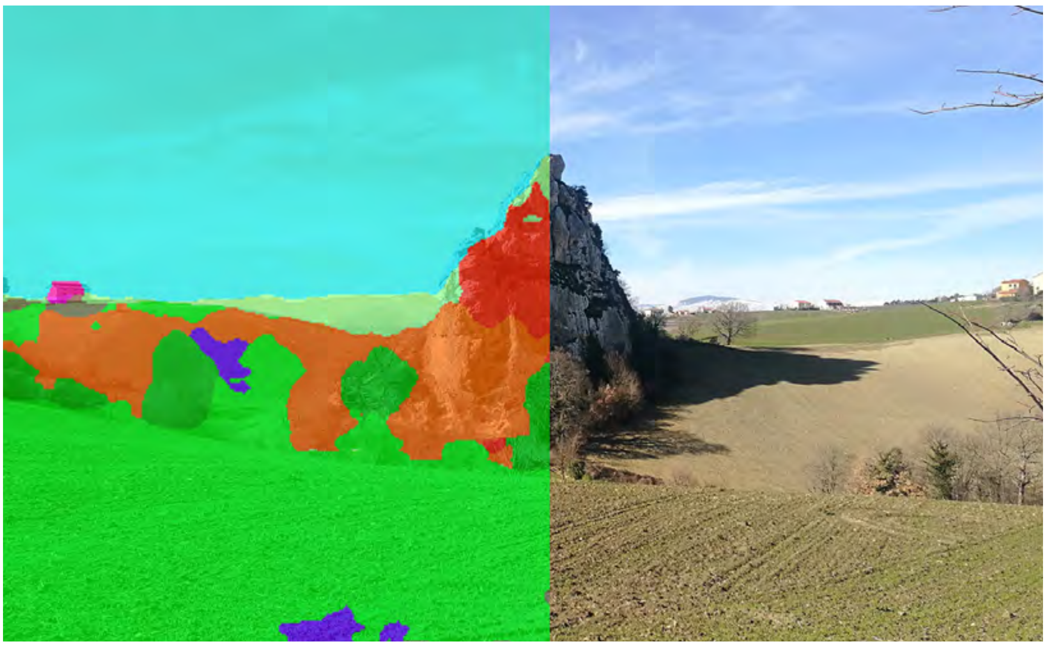
Abstract

The current research aims at investigating the potential of Image Segmentation (IS) as a data source for mapping, with a bottom-up approach, the spatial quality of slow routes, localized in the territories "in-between" the main cities. The paper analyses two different case studies in Lombardy and Molise regions, where a different territorial configuration and data are available. The IS method, that computes area percentages in the street-level imagery by using Pixellab/TensorFlow digital environment, has been applied for detecting three different environments that are intersected by the selected routes and that are also detectable by using GIS tools: open spaces, built environment and rows of trees. These have been considered as relevant since they affect the users' perception of the places in a different way. The research points out how the IS method can be complementary to the GIS-based detection method to collect more detailed geo-information about the places, but also a very powerful tool to catch geo-information by the street-level imagery, in the territories where no thematic geospatial data are available.

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



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Introduction

The method of analysis illustrated in this contribution starts from the assumption that the quality of the experience one feels when crossing a landscape is influenced by the presence of some components of the landscape: open spaces, which guarantee wide views, presence of tree-lined rows that make the route pleasant to follow, proximity to villages and isolated architectural elements, that attract our attention. Of course, the mere presence of these elements does not in itself constitute the general quality of the landscape, but their identification is at the same time crucial in order to then establish, in a second phase of investigation, the specific quality of its components. The survey method was applied in open contexts, where it is more difficult to recognize the elements of value that can be used to determine the best route, as it allows you to pass near the most prestigious places and to cross more pleasant landscapes. It was decided not to apply the method within the main built environments, as geo-referenced information is usually more available within them that can be used to identify the most interesting and preferred path. The method therefore aims firstly to establish criteria for the choice of the slow path of higher spatial quality in the landscapes in between the main urban centers. The method refers to procedures of mapping, meant as a specific creative process for the definition of maps which we consider here as a sort of output of the mapping [Abrams, Hall 2006] through methodologies that are able to accept at the same time information of an objective nature, which adopt a point of view that is not only conceptually external, on the part of experts (or so called outsiders), according to a top-down logic, integrating them with more subjective information, related to the perceptual sphere and according to a logic capable of receiving contributions from users (insiders), according to a bottom-up logic. This methodology has already been developed in previous research experiences, in particular on the topics of the Spatial Quality Index of Slow Routes (SQISR) [Scandiffio 2019], of mapping with image segmentation analysis with identification of significant elements using Mapillary Segmentation [Bianchi et al. 2020; Rolando et al. 2021] and here a more precise definition of the method in landscapes where no GIS top-down information is available and how to implement them with bottom-up techniques.

Case Studies: the Monks Route in Lombardy and the Parco delle Morge Cenozoiche in Molise

The research has been applied to two case studies, characterized by different territorial configurations. The one in Lombardy region is about the Monks Route, a slow route, which connects the Milan city center to Corte Sant'Andrea, by crossing the Po Valley in the north-west to south-east direction, following the Lambro river valley. This route is 64 km long. For most of its length, it crosses open spaces, characterized by a flat agricultural landscape in the southern agricultural park of Milan, which is spotted by historical abbeys (e.g. Chiaravalle and Viboldone), rural hamlets and farmhouses, which are settled along with a network of canals that support agricultural cultivations. This contribution focuses the attention on the route stretch between Civesio and Viboldone hamlet, 1.5 km long, where it is possible to cross three kinds of environments such as open spaces, built environment and rows of trees, which are of interest for the purpose of the current research. The map shows the whole itinerary between Milan and Corte Sant'Andrea, where the Monks route connects to the Via Francigena (Fig. 1a). The other maps show the selected area along the route, localized in the surroundings of the Viboldone Abbey, where the IS methodology has been tested (Fig. 1b). The map also shows the selected geo-localized pictures, taken along the route, which have been used to recognize spatial components of the landscape by the street-level imagery (Fig. 1c).
The second case study is located in the Parco Cenozoico delle Morge in Molise. The landscape where the Morge park is located straddles the valley floor of the Biferno, which crosses the Molise Region, and the Trigno river, which separates it from the Abruzzo Region. The park network crosses the territory between the two arms of the Celano-

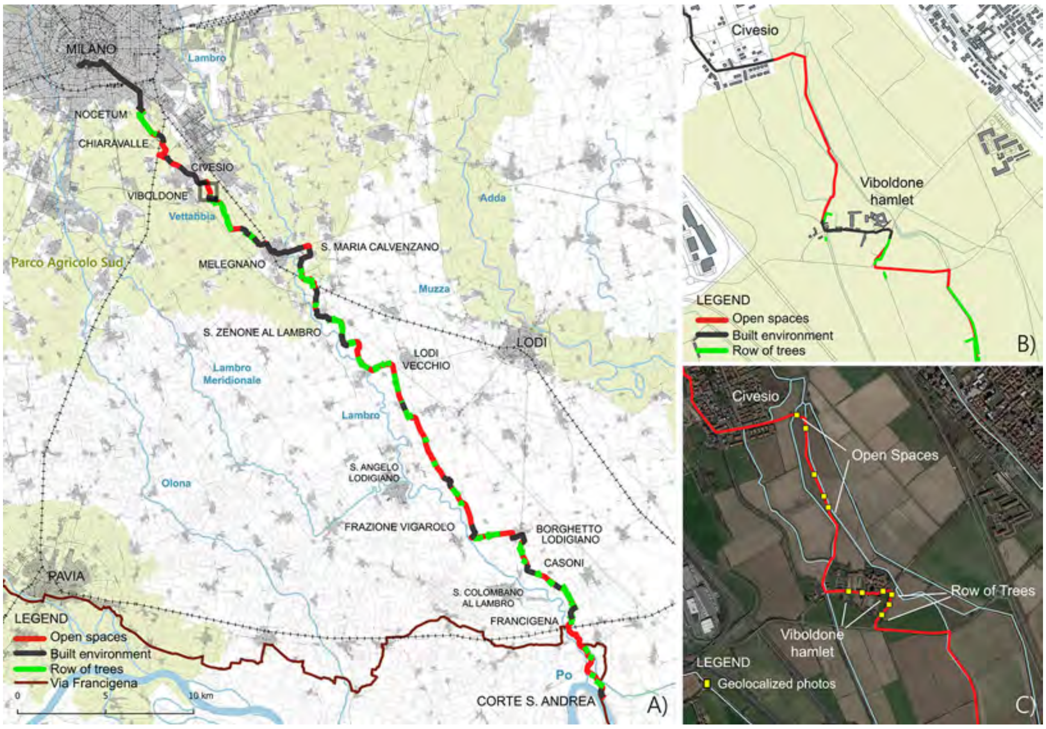

Fig. 1. a) Map of the whole Monks route, which highlights spatial components of the landscape along the route; b) Map highlights the selected area in the surrounding Viboldone Abbey; c) Map shows the selected geolocalized photos in the selected stretch.

Foggia Tratturo, which connects Abruzzo and Apulia. The choice of this area was determined by the presence of a route that crosses the area and enables the discovery of the park, characterized by a hilly landscape, large open spaces, spotted by small historical hamlets. In terms of the availability of thematic geospatial data, the area is characterized by the absolute lack of them, which do not allow a top-down analysis of the area. At the time of writing, the Molise Region has not developed detailed cartography of its territory; therefore, the maps (Fig. 2) have been extrapolated by OpenStreetMap geographic database. The route under study is part of a 75 km itinerary through the Park area [Carulli et al. 2021]. The selected area is extended between Pietracupa hamlet up to Morgia di Pietravalle and it enables crossing the three selected types of environments (open spaces, built environments, the row of trees). The map also shows the geolocalized pictures, taken along the route (Fig. 2b).

Methodology

The methodology of this work stems from the need to assess the quality of the landscape crossed by slow mobility routes, by trying to maximize the data available in the different territories under analysis. It is useful, therefore, to consider different layers of analysis that work in synergy for this purpose, respectively GIS databases and street-level photographic surveys. On the one hand, the top-down analysis with GIS mapping techniques has been performed on the basis of geospatial data availability (Regional portals and open data portals), in order to map the three kinds of environments along the selected routes. The GIS approach, by exploiting the zenithal point of view, which is typical of the maps, enables the mapping of landscape features on large scale contexts. The measurement of the spatial quality of slow routes through GIS has been successfully tested in the area crossed by the Monks route by the SQISR method, by exploiting the potential of geodatabase [Scandiffio 2019]. In the framework of the current research, the GIS approach has been applied to map the three selected landscape features along the Monks route, by using the available datasets on the Lombardy Geoportal. By applying GIS geoprocessing tools, the graded track of the Monks route has been drawn. The track highlights, on the whole route, the

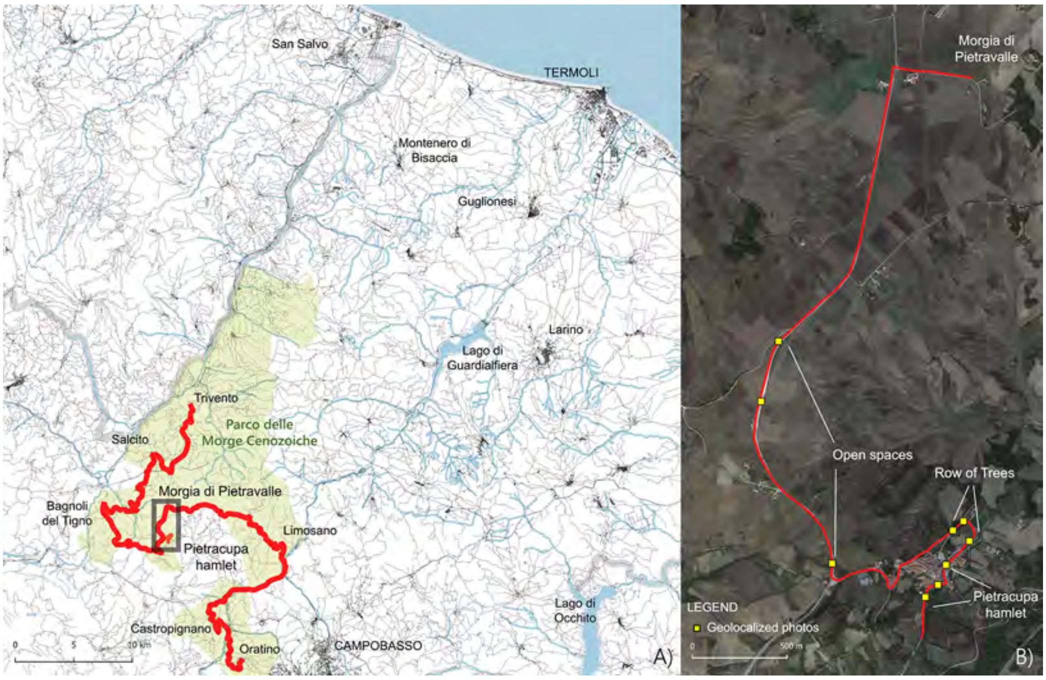

Fig. 2. a) Map of the whole route between Oratino and Trivento in the area of Parco delle Morge Cenozoiche, in the Molise region; b) Map of the selected area between Pietracupa and Morgia di Pietravalle, which shows where the pictures are taken.

spatial distribution of open spaces, built up areas and rows of trees along the route (Fig. 1a). In the Molise Region, it has not been possible to perform the GIS approach through the SQISR method, due to a lack of geospatial data. In this perspective, the big amount of georeferenced street-level imagery, available through the web by Google Street View [Dragomir 2010] or Mapillary [Warburgy 2018] is a big data source [Zhang et al. 2018], for detecting the landscape features along the route from the users' point of view, and also for generating geospatial data on the map.
In this sense, the current research explores the methodology that uses the street-level photographic survey as a basis for the analysis of the territory by Image Segmentation (IS) technology. This system is part of the broader ecosystem of Machine Learning (ML) and allows the automated identification and perimeter of different elements within a photographic shot. A Mapillary photographic survey [Porzi 2020] was used for both study areas for this work. The choice of Mapillary is due to its flexibility in the acquisition of images along chosen routes. Compared with Google Street Map, it is possible to choose every kind of routes, even off-road tracks, and they are available for further analysis right after uploading. Mapillary enables the making of fixed-distance photographic sequences by choosing the distance in-between two consequent photos, showing the exact location and the length of the space crossed.

Unfortunately, a recent update in Mapillary API has disabled IS analysis, which has been the basis for previous work [Rolando et al. 2021; Yang et al. 2022]. Therefore, a different digital engine has been experimented. The snapshots extracted from Mapillary were then processed with the Python library Pixellib [Olafenwa 2022], which allowed the identification of the percentage of image occupation of the elements in the ADE20K dataset [Zhou 2018]. All the elements present are listed for each image, ordered by decreasing percentages of occupation of the total space. Each image has been associated with one of the three environments based on the fundamental elements present and their quantification. The detection of the elements enables the evaluation of the scene from a landscape point of view; they are the only ones to be considered because they are present in quantities greater than 15% and are: sky, building, road, tree, hill, field.

The presence of a very high percentage of the sky element is decisive for the detection of the open spaces. Other elements present in this environment are road, field, and hill.

This element is also of fundamental importance in an absolute sense to quantify the visual field's opening within the limits of correct framing of the photographic survey. In the specific case, the evaluation of photos with a sky presence of more than 60% is discarded due to obvious operator errors in framing. The sky element, mainly detected in extra-urban environments, is always present in the other two environments but it is discarded when the other fundamental elements are present at the height of more than 25%. The built environment is intuitively characterized by the presence of the building element, which clearly identifies the inhabited centers; in the row of trees environment, the presence of the tree element is instead predominant. The methodology explained above was applied to the two case studies by analyzing individual shots taken along the two routes, in Lombardy and Molise, respectively, and analyzed by using the IS digital ecosystem. The methodology has been applied to the Monks route, in the stretch near Viboldone Abbey (Fig. 1c). In this portion, photographs already present in the area were used, located in the open space, in the Viboldone hamlet, and along the avenue bordered by the row of trees immediately beyond. The map shows the spatial distribution of the photographs. From the overall sequence of photographs available through Mapillary, five significant shots were selected for the open spaces environment because of the long stretch and three exemplifying shots for the other two environments (Fig. 1c). A similar approach would have been used for the area in Molise, however, the lack of both cartographic and photographic material led to a customized application of the explained methodology. A photographic survey was carried out with the Mapillary platform along the route through the village of Pietracupa to the Morgia di Pietravalle. The photographic survey [D'Uva 2022] was carried out by taking pictures every 5 meters, divided into two tracks of 300 and 184 photos respectively. The selected geolocalized pictures are visible on the map (Fig. 2b).

Outcomes

The research, by applying IS methodology to the sequence of selected pictures, shows how to identify the average threshold values for each landscape component visible in the imagery (e.g. sky, fields, buildings, trees, walls etc.), which is localized in the selected environment. Within each environment, at least three photographs were selected to which the ML procedure was applied, providing threshold values characterizing the environments in a unique way. In the area of Viboldone Abbey, the open spaces are characterized by the presence of the sky > 50% and the presence of fields > 20% (Fig. 3). Additional elements between 3% and 10% were trees and paths. For the automatic recognition of the built environment, the presence of buildings averaged > 15%, and roads and walls > 30%. Additional elements characterizing this environment are sidewalks, pavements and trees, ranging between 2% and 18%. Finally, the environment characterized by rows of trees is recognizable by an average percentage of trees higher than 40%. In this last environment also the sky can be framed in a range between 30% and 40%.
For the second case study, the Pietracupa area, the open spaces environment, the presence of the sky was detected well over 50%, in addition hills over 20%. Other elements such as road, and trees were detected between 3% and 18%. The hamlet environment is characterized by the predominant building element, over 30%, together with the road element, between 15% and 20%. Finally, the row of tree environment is characterized by the predominant tree element, above 30%. Other detected elements in this kind of environment are road and wall, between 5% and 14%.

Discussion

In the Viboldone area, the comparison between the GIS method and the ML method provides a good match. As it has shown in the previous images (Figs. 1b-1c; Fig. 3), the analysis carried out by GIS, from the zenithal point of view, provides equivalent outcomes

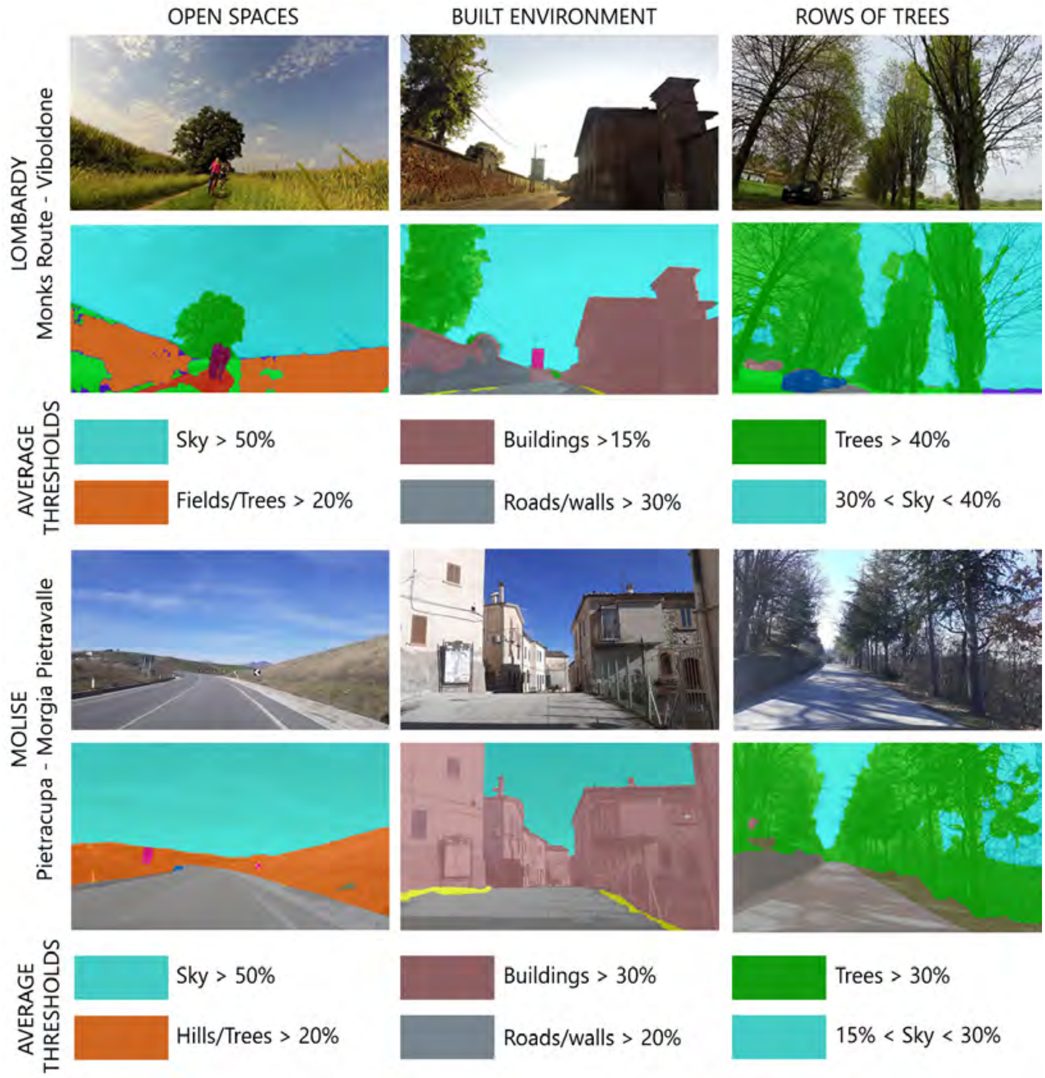

Fig. 3. Analysis of the main outcomes for the selected environments by ML methodology: open spaces, built environment and row of trees. In the case studies of Lombardy and Molise, the methodology provides average thresholds for environment characterization in terms of elements occupation percentage in the imagery.

to the ML analysis, conducted at the street level. In the Lombardy case study, the outcomes performed by the ML method provide precise identification of the environments along the route, as well as they have been mapped through GIS. In this perspective, the street-level methodology seems to be effective to detect the selected environments typologies, even considering the potential of providing much more detailed information about the landscape components (e.g. walls, fences, types of vegetation are very detailed elements, that cannot be detected from the zenithal point of view). Instead, in the area of Pietracupa it is not possible to provide the comparison between the two methodologies, due to lack of geospatial data.
By analyzing the open spaces environment in both case studies, the research finds that the value of the sky element above 50% is a distinctive feature of that space, as well as the sum of the elements fields and trees, or hill and trees above 20%.

In the built environment, it is possible to assume that the building elements plus low percentage of roads, walls, sidewalks are the distinctive features of this environment. By analyzing the both case studies, buildings have different values because of the higher density in the urban fabric of Pietracupa hamlet. To support the measurement of building density contributes the sky value, which is in Pietracupa on average 15%, while in Viboldone, it is 35%. This analysis enables the characterization of the morphological differences of the villages in terms of relationships with the orography of the site, which is different in the case of Pietracupa, where there is a strong acclivity, compared with a predominantly flat landscape in the case of Viboldone.

A necessary but not sufficient condition for identifying the row of trees environment is intuitively the predominant presence of trees. However, their presence alone is not sufficient to characterize the row geometrically as a linear entity along the route. In this case, the digital technology of Instance Segmentation would allow counting the elements in the photos, making evident the differences of the linear vegetation of the row compared to the forest vegetation, which can be considered instead as an aerial entity.

Studies within this work have shown that in order to be able to define the beginning and end of the elements detected with the interpretation of street-level images, it is essential to work on a sequence of images, the distance of which is sufficiently short.

Conclusion and Future Developments

The research has shown the potential of IS methodology as a tool to assess the spatial quality crossed by slow routes as a complementary tool to the GIS or as a source of information when no other thematic geospatial data are available beyond the photographic survey. In this last condition, IS methodology can be used to detect spatial information of the places, with the aim to transpose the surveyed features on the ground to the map, through photogrammetric procedures. In this last operation, it is crucial to take into account the number of shots along the route to get an adequate level of accuracy on the map.
In order to improve the effectiveness of the method for assessing the spatial quality of slow routes, it would be relevant if the specific contributions, related to GIS and IS, are well integrated with each other. In this perspective, a broader integration between both methods, at street-level and zenithal, but also in relation to Remote Sensing [Rui 2018] and to users' contribution (e.g. social networks, big data derived from them, questionnaires) would allow a deeper knowledge of this challenging topic. New research perspectives can be addressed to investigate a better integration between the mentioned methods and mapping techniques.

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Real-Time Identification of Artifacts: Synthetic Data for AI Model

Andrea Tomalini
Edoardo Pristeri

Abstract

The collections represent the constitutive element and the *raison d'être* of each museum. Their management, care and dissemination are therefore a task of primary importance for every museum. Applying new Artificial Intelligence technologies in this area could lead to new initiatives. However, the development of certain tools requires structured and labeled datasets for the training phases which are not always easily available. The proposed contribution is within the domain of the construction of specific datasets with low budget tools and explores the results of a first step in this direction by testing algorithms for the recognition and labeling of heritage objects. The developed workflow is part of a first prototype that could be used both in heritage dissemination or gamification applications, and for use in heritage research tools.

Keywords
heritage, museum collections, image recognition, synthetic dataset, machine learning.

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Introduction

Museum collections represent a part of our cultural heritage and as such are testimony of our past, enrich the present and inform the future. This is sufficient motivation to establish that it is essential to increase the perceived value of these artifacts also through new methodologies. Using Artificial Intelligence (AI) techniques, is however a rather challenging task: there are relatively few datasets to use for smart applications, and the metadata associated with images is often poor and unstructured, or does not exist.
To answer the last of these issues, this paper presents a first prototype which, starting from photogrammetric acquisitions, builds synthetic datasets of correctly labeled images to train AI algorithms capable of labeling museum objects.
AI frameworks capable of classifying image contents have already achieved some success in various fields, these can be conceptualized as memories capable of being recalled to perform a certain task. It follows that the construction of a memory is the most delicate phase for the development of these algorithms and it is essential, whether we are talking about Machine Learning or Deep Learning, to have access to a large data set of labeled images on which to perform the training phases. As for everyday objects there are numerous sets available, the same cannot be said for heritage artifacts. In this case it is necessary to acquire the data and then label it, these operations are quite long and, consequently, expensive. The proposed prototype – born from the collaboration of a research group of the Department of Architecture and Design of the Politecnico di Torino, a working group of the LINKS Foundation and the Museo Egizio of Turin – suggests an economic method for the creation of a labeled image dataset automatically. As anticipated, the proposed workflow is based on the acquisition of the artifacts through photogrammetric survey techniques. The high-fidelity textured mesh of the object obtained is processed by Physically Based Rendering tools for the creation of image datasets for training the algorithms.

Related Works

The development of high-performance computing systems, advances in the design of the software architecture structure and, above all, the availability of large photographic datasets, have been the main factors that have pushed the classification and detection methods to success. On AI systems, datasets such as MS COCO with more than 300,000 images [Lin et al. 2014], have certainly contributed to the research and development of these frameworks. However, photographic datasets are not always easily available, especially if they are datasets concerning objects not in common use.
To date, with regard to semantic segmentation in the context of cultural heritage, there is still a scarcity of significant photographic datasets. Examples have been reported in the bibliography in which, to overcome this problem, the transfer learning technique was applied. This technique consists in using large and generic datasets (such as the one previously cited) along with a reduced set of images containing the object target of the recognition problem. [Marinescu et al. 2020].
The use of 3D models for the construction of synthetic datasets for image classification is a fairly recent area of research and appears to be a rather promising technique, complementary to the one described above [Nowruzi et al. 2019] [1]. In the bibliography there are some examples in which researchers have used synthetic datasets to train neural networks, for example NVIDIA researchers have created 60,000 annotated photorealistic renders of objects that are in free fall now collected within the open "Falling Things" (FAT) [Tremblay et al. 2018]; several researches were conducted to test the goodness of synthetic datasets for the recognition of objects in a domestic or commercial environment, in this case the physical environment surrounding the object to be recognized was also analyzed and (therefore taking into account occlusions or positions random and unusual object and observer's chamber), in all cases, it was underlined how the results obtained are promising and how it is much more important to generate random images that simulate more the randomness

of the physical environment, rather than photorealistic [Mitash et al. 2017; Rajpura et al. 2017; Hinterstoisser et al. 2019]. The semantic segmentation problem [2] has also started to benefit from these synthetic datasets, with the creation of virtual scenes to perform the segmentation of indoor environments [Handa et al. 2015; Papon et al. 2015]. On the basis of this research and strengthened by the previous research experience [Tomalini et al. 2021] the group has re-designed the methodology of construction of the datasets to reduce the problem of overfitting caused by the reduced variability of the developed synthetic dataset [3] and to increase the overall robustness.

Case Study

In collaboration with the researchers of the Museo Egizio of Turin, two pairs of vases were chosen as a case study: the first pair is labeled as Class B, Black Topper Pottery, belonging to the Predynastic Period, Naquada I (4500-3100 BC); the second pair is labeled as Class R Rough Faced of the Old Kingdom, III-IV dynasty (2680-2140 BC).
Given the initial state of the research, these artifacts were selected because the classes to which they belong are identifiable by peculiarities that are rather easy to recognize. It follows that the classification algorithms used for these artifacts in this work are simple and based on a reduced number of characteristics. The Class B, Black Pottery is characterized by this crown of black pigment at the mouth and lip of the vessel, the rest of the body is red. Class R, Rough Faced is characterized by the absence of decorations and by its very rough ocher-colored surface.

Data Acquisition

As anticipated, the vessels were detected through photogrammetric techniques. However, to assign a correct scale to the model, and consequently ensure a good rendering, the cloud was scaled on the basis of known points (belonging to the artifact such as: cracks, imperfections or stains) previously acquired with the aid of a scanner. structured light. The instrument used, with accuracy from the technical data sheet of 0.3mm, is not able to return a faithful texture and for this reason we have preferred to use an integrated approach. The instrumentation used was a Sony Alpha 6000 equipped with a 23.5x15.6 mm sensor and a first generation Revo Point POP structured light scanner. Despite the unprofessional and low cost tools, it is known in 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].

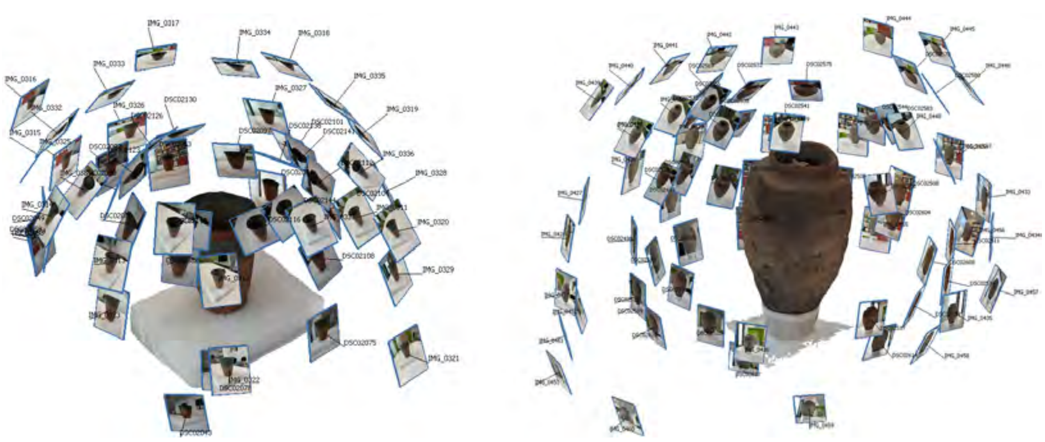

Fig. 1. Photogrammetric acquisition, Metashape interface. On the left a Class B vase, Black Topper Pottery; On the right a Class R Rough Faced vase.

The proprietary HandyScan software was used to manage the scanner information, the Agisoft Metashape software for the calculation of the photogrammetric cloud, the first mesh and final texture (Fig. 1) and the 3DReshaper software for cloud cleaning and mesh refinement operations. The output of these operations is a high fidelity textured mesh of the objects under examination (for the pair of Class B pots, Black Topper Pottery there are two meshes of 27,506 vertices and 29,113 vertices, for the Class R Rough Faced pots there are two mesh of 25,232 vertices and 28,849 vertices).

Dataset Creation

As suggested by the bibliography and the experiments conducted previously, a good synthetic dataset must be characterized by a good level of heterogeneity and contain sufficient images to be able to correctly recognize the instance to be classified. The proposed workflow for creating these render images for training AI frameworks is divided into 4 phases:
– The first phase consists in the generation of the textured mesh. The optimized, textured mesh is used as input to an algorithm written in Rhino's Visual Programming Language (VPL) environment. The mesh is recognized dimensionally through the creation of a bounding box which also identifies its barycentric point. This point is used as a base point for creating a sphere with a radius sufficient to contain the object. A chamber is positioned on each vertex of the tessellated sphere whose center of gravity is the center of gravity of the object. Depending on the different needs, the sphere is tessellated more or less finely: a smaller number of faces allows a reduction in calculation times, on the contrary a greater number of faces will generate a richer dataset. In this specific case, 320 photorealistic images of the single object were generated in two lighting conditions (to simulate two different locations within the museum environment). The images are 480 * 480 pixels in size and have been exported in .png format with no background. The automated process has integrated a PBR (V-Ray) rendering engine for better rendering (Fig. 2).
– Using a Python environment, the images containing the object's renderings are then processed to calculate its outline, to be used in the dataset annotation phase, and their insertion within images containing background scenes.
In the script we have developed for this use case, the images are first imported using the OpenCV library [Devjyoti 2021]. During the import process the alpha channel is preserved which allows us to exploit transparency to our advantage, using the border of the non-transparent region as the object contour.

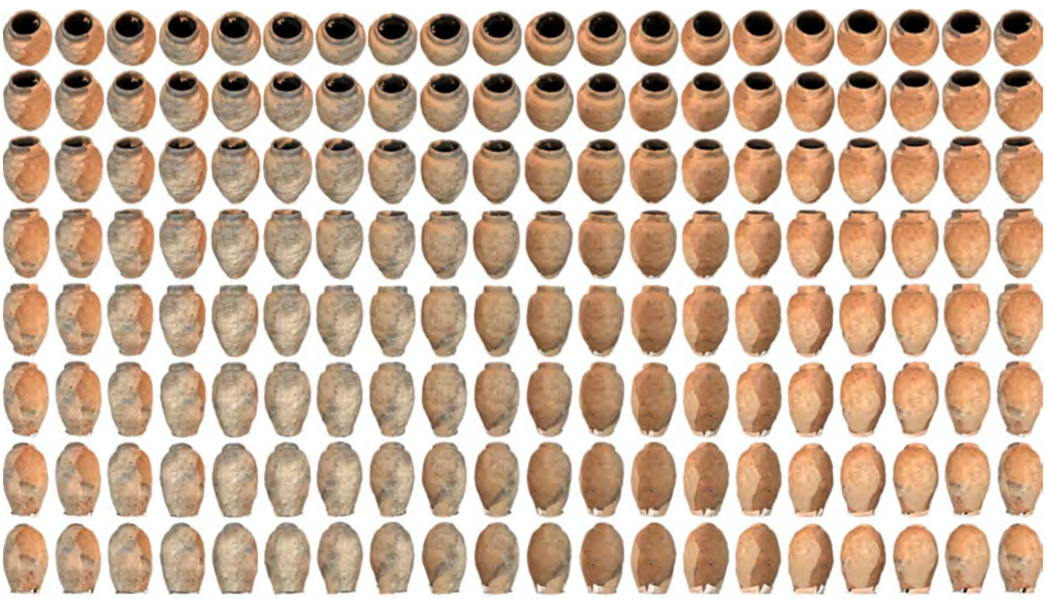

Fig. 2. Rendered images of a Class R Rough Faced vase.

Fig. 3. Two images of the synthetic dataset. Random background of the SUN dataset and green outline annotation.

However, the contour identified with this method is too complex and jagged to be used for training our neural network. We then proceed by applying the Ramer-Douglas-Peucker algorithm, an algorithm that reduces a complex curve composed of numerous line segments into a similar curve but with fewer points.

– Once the outline has been extracted, the renderings are inserted into images containing backgrounds, which are useful for mitigating overfitting problems. The background images were extracted from the Scene UNderstanding (SUN) dataset [Xiao et al. 2010]. This dataset is commonly used to perform environment recognition operations. In this case we have extracted via API a set of random images, of cardinality equal to the dataset we generated, starting from the dataset in question. Our goal is to generalize as much as possible the environment in which we are going to insert our objects to ensure that the learning process of the neural network focuses on the objects and not on the background. To further increase the learning robustness, the images of the objects are anchored to a point of random coordinates within the background image, a scaling and rotation operation is also applied in advance to the object before the end of the operation. insertion. The parameters of these transformations are saved and then applied to the outline of the previously extracted object to ensure that it is consistent with the coordinate system of the background image in which the object was inserted.

– Once the operation is complete, the image is then saved together with the corresponding annotation file containing information on the outline of the object within the image. The annotation file is a .json format file compatible with the standard used by the VGG Image Annotator (VIA) tool. This format was chosen to maintain compatibility with manually annotated files.

The examples in Fig. 3 show two examples of annotated files with the outline (green) and its points (red) highlighted.

Neural Network Description

To carry out the recognition of the objects to be classified, two approaches based on different architectures have been explored. The two architectures considered are YOLOv5 and Mask_RCNN.

The most obvious difference between the two architectures is the method by which the searched object is highlighted within the image. The goal of YOLO is, being designed for real time detection scenarios, to identify the object as quickly as possible, yet only drawing a bounding box around it. On the contrary, the Mask_RCNN architecture [Waleed 2017], considered as the successor of Faster R-CNN, is a framework that allows you to perform object instance segmentation operations albeit with a slight performance impact [Buric et al. 2018].

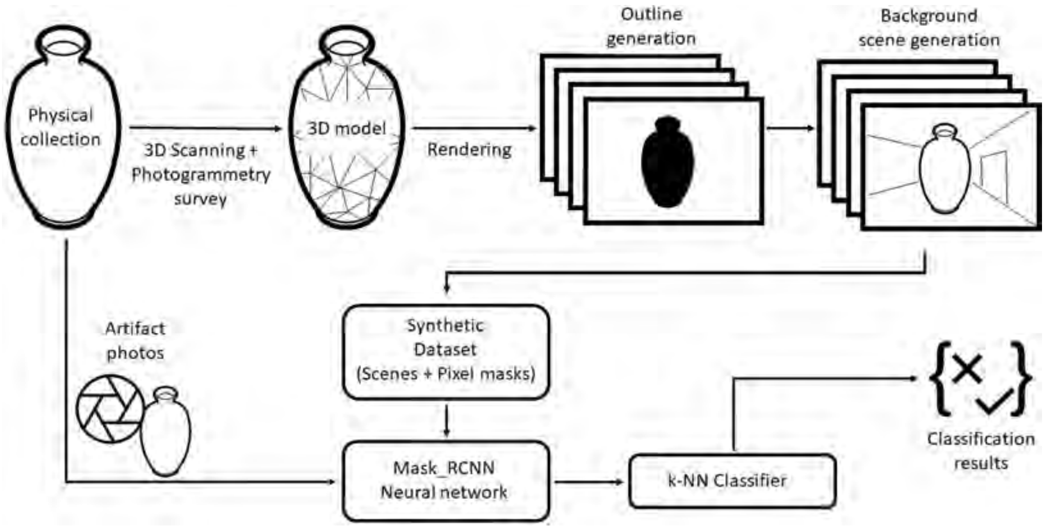

Fig. 4. Workflow overview.

Given the absence of stringent requirements on the time necessary to carry out the recognition of the objects in this use case, after an initial phase of experimentation it was decided to use the Mask_RCNN framework given the advantages brought by the semantic segmentation in the identification process of the artifacts treated by this paper.

Semantic segmentation, unlike simple object detection, provides more information. With this technique the object is not localized with a simple bounding box, the semantic segmentation provides the exact number of pixels and their position within the identified object as a result. In the event that there are more than one object in an image, each object is marked with its own color, allowing the individual objects to be identified visually. The possibility of extracting the objects from the background using the mask will allow us to use simple classification algorithms which won't be confused by the noise coming from the background data (Fig. 4).

The Mask_RCNN implementation used in this paper is available at Matterport / Mask_RCNN. Given the consistent hardware requirements to train the network from scratch, it was decided to use the transfer learning technique described above to reduce these requirements. In this case weights trained on the COCO dataset were used. The training images correspond to the ones generated by us synthetically. For this procedure, the images have been resized to have a maximum size of 128px on the long side. For the validation dataset, real images used to prepare the 3D models of one vase per pair were used, annotated manually. The images of the other vase of each pair were used as the testing dataset. As for the parameters of the neural network, the batch size was kept at 8, having a single Nvidia 1080Ti GPU available. Finally, a class called "vase" has been defined, corresponding to the objects we are going to recognize. In this first experimental approach it was decided not to carry out the classification of the vessels through Deep Learning but only subsequently with simple Machine Learning algorithms.

Fig. 5 shows the results of the detection process on images belonging to both types of vessels. You can see how the vases have been recognized with an average accuracy of about 90% and how the mask mostly respects the original shape of the objects.

As introduced above, in this specific case, to implement the last step of the recognition pipeline proposed by us it was sufficient to apply a clustering algorithm to the RGB values of the pixels contained in the regions identified by the Mask_RCNN network. The fact that the categories of vases used in this research showed some clear differences between them allowed us to classify them simply by using the color value of the pixels belonging to them. In fact, since the network allows exporting the points of the mask identified, these points have been used and imported by a further Python script which clusters their colors. The three dominant clusters of colors were indeed effective when used to classify the images, using a k-NN algorithm implemented in the Scikit-learn Python library. A future possible

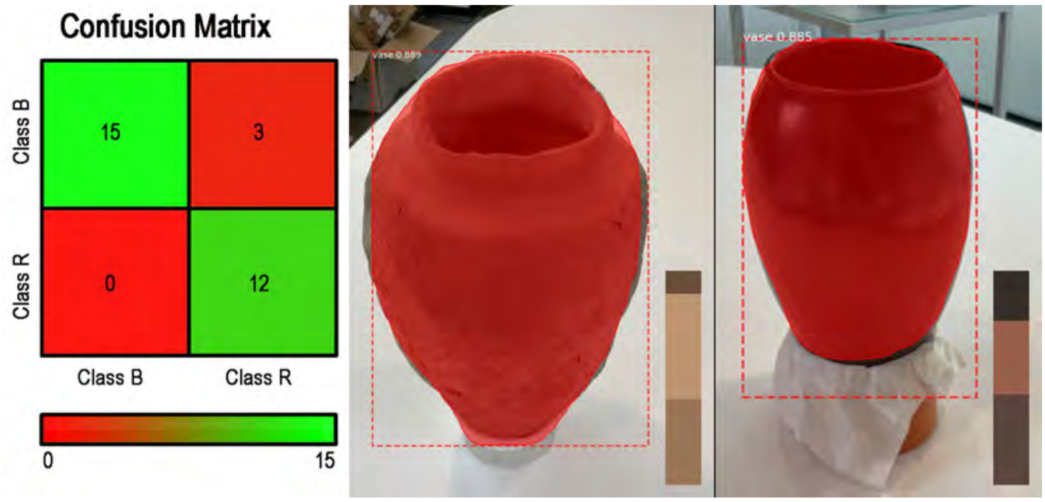

Fig. 5. On the left the Confusion Matrix sows how the accuracy of the k-NN classification algorithm on the test dataset (30 images, 15 for each class of vase) has been 90%, split into 100% for Class B vases and 80% for class R vases;
On the right the results of the detection process.

development of particular interest would be to evaluate the accuracy of a Mask_RCNN network in which the different vessels are considered as different classes, thus using only the DL approach to carry out the classification. This could be useful in classificating objects which are harder to distinguish.

Conclusion

One of the main limitations of Artificial Intelligence algorithms is their need to have more and more data for the training phases and in fields of application such as that of museum collections this problem is even more evident. This paper presents an approach to improve the accuracy of the detection of objects belonging to museum collections through the structuring of synthetic datasets automatically labeled with low budget instrumentation. Given the really promising results, the research group intends to further optimize the proposed workflow to make it more flexible and further scalable.
The application cases on which innovation can be implemented by implementing image recognition as described in the paper are many and can involve different users: from gamification applications for the general public; the creation of research tools for museum professionals.
In the first case, it is not difficult to imagine the programming of tools that improve the museum experience. In the bibliography it is known how AR systems, if properly combined with object detection algorithms, can expand the level of knowledge that can be accessed [Spallone et al. 2020]. Through these tools, the user, no longer bound to QR codes or didactic panels, can explore the collection and dwell on the artifacts that most intrigue him.
In the second case, through a different commitment of resources, one could arrive at tools for monitoring the collections present in the museum, or at the creation of *ad hoc* tools that simplify the operations carried out by the researchers to classify the new finds.
The working group undertakes to further study the topic and to identify case studies on which to apply the AI models trained through this workflow.

Notes

[1] It is interesting to report the conclusions of Nowruzi's research group as they noted that within a synthetic dataset it is more important to achieve a certain level of heterogeneity rather than a high photorealistic accuracy.

[2] Classification: By classification we mean the task of assigning a single label to a data (an image in our case) entering the model; Semantic segmentation: The segmentation of images is a fundamental part for Computer Vision systems which consists in partitioning an image into different regions representing the different objects; Object Detection: Detection is defined as the task of finding rectangular regions of an image, in which objects of interest are represented. These regions, called Bounding Boxes, are then classified to describe the object they contain; Instance Segmentation: Instance Segmentation is challenging because it requires the correct detection of all objects in an image and their segmentation or the definition of the exact perimeter and area occupied by the object. It therefore combines elements from classic computer vision tasks such as Object Detection and semantic segmentation.

[3] Among the various metrics calculated during the training of a neural network is the loss function, which allows you to have a measure of how much the algorithm has managed to learn from the data that has been provided. The error calculated by this function can have different components. One component is formed by the so-called irreducible errors, which cannot be reduced regardless of the algorithm that has been applied. Another factor is made up of the so-called reducible errors including, for example, the error defined by the difference between the value that was predicted by the model and the one you are trying to predict. When the value of this error is very high it is then possible that the model is experiencing an underfitting problem. When, on the other hand, it happens that the model has difficulty in identifying the correct predictions on real data and on the contrary the error is very small on the dataset used to train it, in this case we speak of a possible overfitting.

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