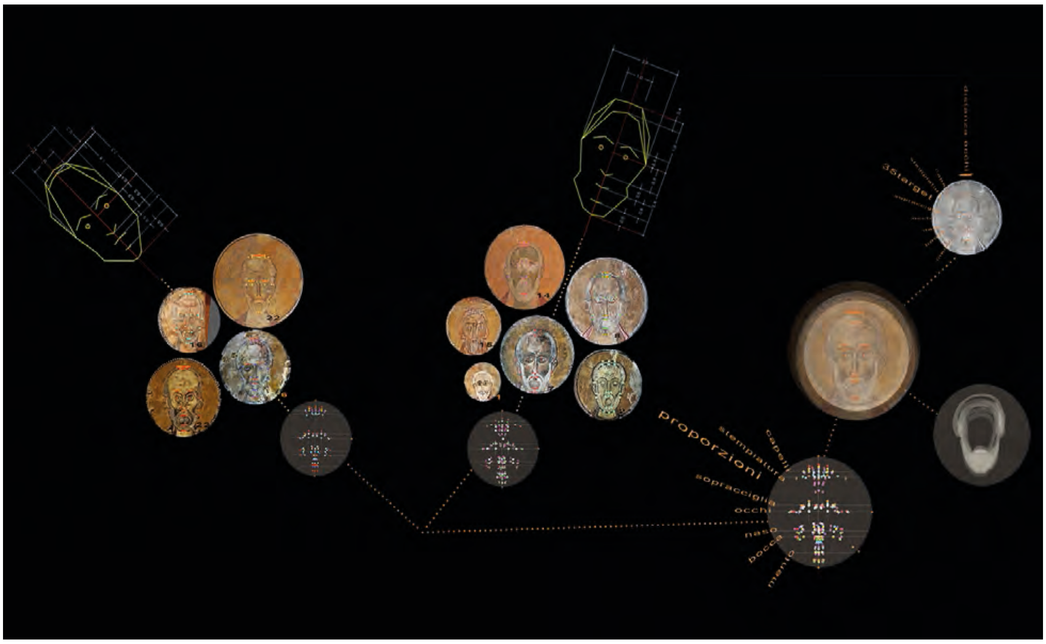
Saint Nicholas of Myra. Cataloguing, Identification, and Recognition Through AI

Marinella Arena
Gianluca Lax

Abstract

This research elaborates a strategy to guide users and scholars in the Byzantine iconographic world, highlighting the elements that contribute to recognizing the sacred figures represented [2]. It develops two visual approaches: on the one hand, the recognition of faces through a database; on the other hand, the use of artificial intelligence for face recognition. The results of the research can be applied to the development of content for new media edutainment; for the digital restoration of the frescoes; for the communication and enhancement of the asset itself.

Keywords
AI, iconography, Byzantine, Saint Nicholas of Myra.



doi.org/10.3280/oa-686.17

Research Protocol

Byzantine iconography is an extremely complex phenomenon [3] for both the syncretism of different cultures and the rigid rules underlying the production of sacred images. The historical events that accompanied the expansion of the Byzantine culture in the Mediterranean area, the repeated Arab invasions, and the transition from the Eastern to the Latin rite have compromised the morphology of sacred architecture and their iconographic apparatus. The rock architectures are directly linked to the migration of monks who, under the influence of iconoclastic struggles and repeated Arab invasions, sought shelter by migrating from the East, Cappadocia, to the West, southern Italy and eastern Greece (fig. 1).
For obvious reasons, the rock churches are isolated, difficult to reach, and often abandoned.

Fig. 1. Rock churches of the oriental rite. Localization of surveyed case studies and formal references.

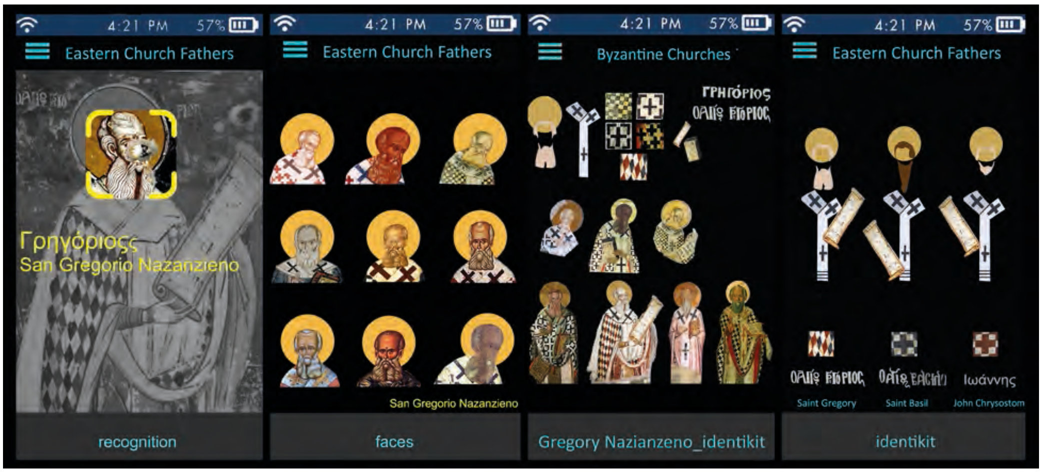


Fig. 2. St. Nicholas of Nazianzen. Identification system based on an iconographic database.

The resulting disuse, paradoxically, preserved them by excluding from continuous adjustments to the changing needs of the cult and society. At the same time, the abandonment, together with numerous deliberate damages of the iconoclastic era, compromised the legibility of the iconographic apparatus. The proposed system guides users into the Byzantine iconographic world, highlighting the elements that help recognize the represented sacred figures. This system can be developed in two different ways: by recognizing faces already presents in a database or by using artificial intelligence to recognize faces and virtually restoring them (fig. 2). In the first mode, the system identifies the representation of the Saint, offering a comparison with other images present in the neighbouring regions and highlighting recurring elements [4]. Moreover, the system underlines the elements that contribute to the identification of the saint himself [Grotowski 2010; Innemée 1992].

The second mode, which uses AI to analyse the morphology of the face of St. Nicholas of Myra, is useful for recognition and virtual restoration [Maronidis 2014].
Four phases describe the research strategy: 1) definition of the survey field; 2) choice of the case study; 3) definition of the AI workflow; 4) application of the obtained results to recognition and reality enhancement.
The field of investigation is divided into two parts. In the former, the architectures that can be part of a circuit of rock churches that are homogeneous in terms of dating, geographical location, iconographic apparatus and analyses carried out. These churches date between the ninth and fourteenth centuries and belong to the ancient Thema of Sikelia, (transformed after the Arab conquest into Thema of Calabria) to the Thema of Langobardia (the current Puglia), and to the Thema of Hellas, in Thessaly. In the latter part, the need to broaden the survey base and give strength and structure to the automated AI process leads us to include the iconographic apparatus of many other architectures, which belong to the southern part of the Mediterranean, and homogeneous to the first ones for dating [5].
The case study is the effigy of St. Nicholas of Myra, widespread throughout the south. The effigy of the Saint appears very repetitive and codified. For this reason, this effigy is suitable for an analytical investigation that starts from some preliminary morphological hypotheses.

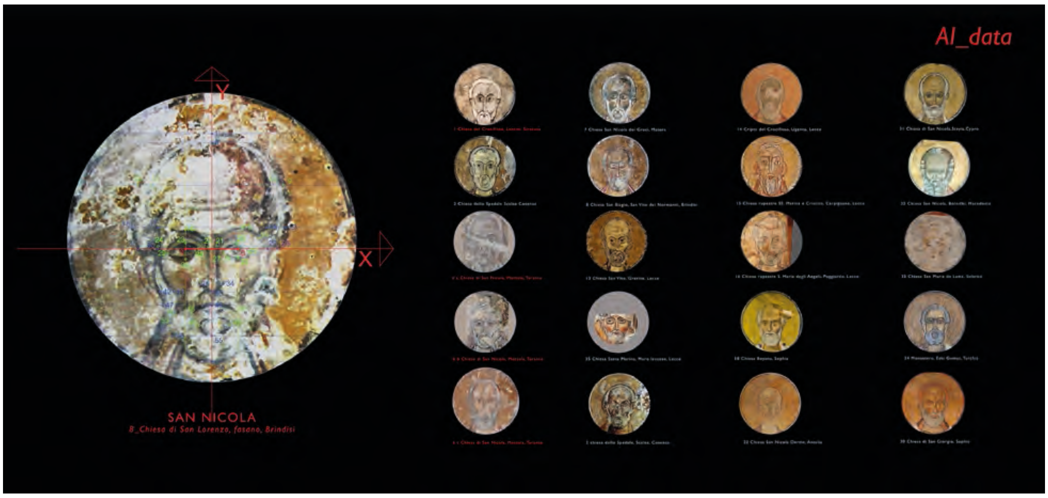


Fig. 3. AI, input data of the reference models.

AI Workflow

The artificial–intelligence–based technique used to analyse the effigies of Saint Nicholas has been implemented in Python and exploits the Scikit–learn library [https://scikit-learn.org/]. The considered input is the set of 19 images of Saint Nicholas reported in fig. 3. The workflow involves three phases.
1. In the first phase, the model input was generated. To identify the position of each point on the face, a reference system with abscissas and ordinates was used that marks the vertical symmetry axis of the face and centres the distance between the pupils. This distance is constant in all images and makes a proportional comparison between the selected images. For each image, the positions of 50 specific points of the face have been identified and measured in the two–dimensional Cartesian coordinate system.
Specifically, we show in fig. 3 the points selected in the face are marked by three different colours. We mark in blue the points related to the proportions of the face, such as face width and height, eye position, nose, and mouth. Green is used for the points related to the morphology of the somatic features, such as the shape of eyes, mouth, and beard. Finally, the points that cannot be detected on a single face are marked in black.
2. In the second phase, missing data have been replaced by the mean of the column, and obtained data have been normalized into the range 0 and 1.
3. In the third phase, we used the k–means clustering method to partition the images into

several groups in such a way that images with similar characteristics belong to the same group. We varied the number k of clusters, and the results of these analyses are discussed in the next section.

Conclusion

We performed several analyses varying k (i.e., the number of clusters). For space limitations, we report the results of the most interesting experiment with k=3. The three clusters show differences in the face size and lip crease and do not seem to identify a partitioning related to the painting dating or the geographical location (fig. 4). in a further analysis, we overlapped the images in the same cluster and tried to 'visualize' the distinctive features of the faces. The division into clusters becomes more precise and a differentiation emerges: the reduced size of the forehead (cluster 2) or the size of the beard and chin and the more pronounced fold of the lip downwards (cluster 1). Cluster 0 shows intermediate features.
The experimentation is only at the beginning, and we expect that with the introduction of other data and the collaboration of an Iconographer, it will also be possible to obtain a reliable hypothesis for the reconstruction of the missing parts (fig. 5).
The model obtained with AI made it is possible to identify some preliminary strategies for the morphological classification of the iconography of St. Nicholas through the identification of the complex proportional relationships between the parts of the face. The results of the recognition and cataloguing carried out by artificial intelligence can be applied to: creation of implementable databases for the dissemination and documentation of the Byzantine iconographic heritage; development of content for new media related to edutainment; digital restoration of the asset; communication of the asset aimed at the enhancement and consequent conservation of the asset itself.

Fig. 4. AI clustering results.

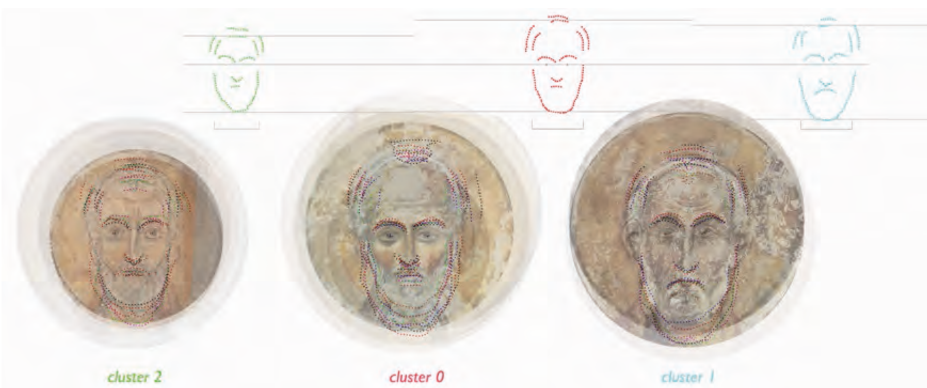


Fig. 5. AI clustering: visualization of the data obtained.

Notes

[1] The research presented in this paper is the result of the joint work of the two authors. The Research Protocol is created by Marinella Arena, the AI Workflow is in the name of Gianluca Lax, the Conclusion is jointly signed.

[2] IThis study is part of a wider research, between Ionio and Egeo conducted with Daniele Colistra and Domenico Mediati, which has surveyed many sacred buildings of the Byzantine era.

[3] "at the actual stadium of our knowledge we are not able to establish links between the saved pieces of art and the social structure or the byzantine geography (...) some general facts reaffirm this pessimistic attitude: the systemic anonymity of the byzantine pieces of art, the extreme lack of the written sources, caused by the disruption of almost all the archives; in the end the insufficient differentiation between the pieces of art." [Grabar 1964, pp. 27-28].

[4] Just as in language few signs, combined differently, generate a multitude of words, similarly in Byzantine sacred representations the sacred vestments, the nimbus, the homophorus, the polistavrion, or the receding hairline, the colour of the hair, or the shape of the beard, identify the Saint's figure. Cfr. "Pursuing the 'representation' rather than the 'imitation', Byzantine artists used a limited range of forms. Within these stylistic norms they changed the physical appearance by modelling the shape of the head and the outline of the cheeks. They used lighter or darker pigments to achieve different skin tones. A wider colour and variety of form was possible in depicting hair and beard. They could be dark, red or white, long or short, whereas the absence of beard and moustache was meant to suggest young age. This method allowed the creation of a very limited number of face–types. This is confirmed by monotonous descriptions in iconographic manuals and eikonismos collections." [Grotowski 2010, pp. 137-138].

[5]. Geographical and chronological location of the case studies: 1_Chiesa del Crocifisso Lentini, Siracusa, 1000; 2_Chiesa dello Spedale, Scalea, Cosenza, 1000; 2b_Chiesa dello Spedale, Scalea Cosenza, 1000; 6 a_ San Nicola Mottola, Taranto, 1100; 6 b _San Nicola Mottola, Taranto, 1300; 6 c _ San Nicola, Mottola, Taranto, 1300; 7 _ San Nicola dei Greci, Matera, 1200; 8_ San Lorenzo, Fasano, Brindisi, 1200; 13_ San Vito Gravina, Lecce, 1300; 14_ Cripta del Crocifisso, Ugento, Lecce, 1350; 15_ SS. Marina e Cristina, Carpignano, Lecce, 959; 16_ S. Maria degli Angeli, Poggiardo, Lecce, 1200; 18_ Chiesa Boyana, Sophia, 1250; 22_ San Nicola, Derme, Antalia, 800; 30_San Giorgio, Sophia, 1250; 31_ San Nicola, Steyis, Cypro, 1100; 32_ San Nicola Bolnicki, Macedonia1350; 34_ Monastero Eski Gumus, Turchia1000; 35_ S. Marina, Muro Leccese, Lecce, 1087

References

Beckwith John (1967). *L'arte di Costantinopoli, una introduzione all'arte bizantina (330-1453)*. Torino: Einaudi. (Original: T*he art of Constantinople, An Introduction to Byzantine Art*. London: Phaidon Press, 1961).

Florenskij Pavel Aleksandrovič (2002). *Le porte regali. Saggio sull'icona.* Milano: Adelphi.

Fonseca Cosimo Damiano (1970). *Civiltà rupestre in terra jonica.* Milano: Carlo Bestetti Edizioni.

Grabar André (1964). *Bisanzio.* Milano: Il Saggiatore (Original: *Byzance*. Baden Baden: Holle Verlag).

Grotowski Piotr Ł. (2010). Defining the Byzantine Saint, Creating a Message in *Orthodox Art in Towards Rewriting? New Approaches to Byzantine Archaeology and Art*. Warsaw: P. Ł. Grotowski and S. Skrzyniarz.

Innemée Karel C. (1992). *Ecclesiastical Dress in the Medieval Near East.* Leiden: Brill.

Maronidis Anastasios, Voutounos C., Lanitis Andreas (2014). Designing and Evaluating an Expert System for Restoring Damaged Byzantine Icons. In *Multimedia Tools and Applications,* June. New York: Springer Science+Business Media.

Medea Alba (2014). *Gli affreschi delle cripte eremitiche pugliesi.* Lecce: Capone.

Robinson Gertrude (1930). Some cave chapels of Southern Italy. In *The Journal of Hellenic Studies*, 50 (2), pp. 186-209.

Settis Salvatore (2005). *Iconografia dell'arte italiana 1100-1500: una linea.* Torino: Einaudi.

Thierry Nicole, Thierry Michel (1963). *Églises rupestres de Cappadoce, région du Hasan Dagi.* Paris: Librairie Klincksieck.

Authors
Marinella Arena, Dept. of Architecture and Territory, dArTe, University of Reggio Calabria, marinella.arena@unirc.it
Gianluca Lax, Dept. of Information Engineering, Infrastructure and Sustainable Energy, DIIES, University of Reggio Calabria, lax@unirc.i

 Isbn 9788835125280

Prosthetic Visualizations for a Smart Heritage

Stefano Brusaporci
Pamela Maiezza
Alessandra Tata
Fabio Graziosi
Fabio Franchi

Abstract

The development of ICT has favoured the spread of real–time, pervasive and ubiquitous applications. In particular, VR and AR visualizations allow a close interrelation between people, data, environments and objects. Consequently, it is possible to enrich cultural heritage with information by visually superimposing multimedia content, in absolute respect of their physical consistency. In this way, it is possible to create a 'smart heritage' dimension that combines the potential of the 'Phygital' with the protection and enhancement of assets often characterized by important elements of fragility. An important role is played by AI applications, which automatically direct the processes of 'Interpretation' and 'Presentation' of the heritage. Based on the experience of the 3D reconstruction of the no longer existing Baroque configuration of the Basilica of Collemaggio in L'Aquila, aim of the paper is a theoretical–methodological reflection on the concept of VR / AR / MR for cultural heritage.

Keywords
augmented reality, architectural heritage, 3D modelling, smart heritage, digital heritage.

doi.org/10.3280/oa-686.18

Introduction

The development of ICT has favoured the spread of real–time, pervasive and ubiquitous applications, which allow the interrelation between information, people and environments. In this way, thanks to smart devices, each user is constantly immersed in an on–life state [Floridi 2015]. In this context, Artificial Intelligence (AI), combining data, algorithms and computational power through machine learning processes, plays a very important role. In particular, the *White Paper on Artificial Intelligence: a European approach to excellence and trust* [European Commission 2020] highlights the potential of AI for citizens, economic activities and the public good: "the impact of AI systems should be considered not only from an individual perspective, but also from the perspective of society as a whole. The use of AI systems can have a significant role in achieving the Sustainable Development Goals, and in supporting the democratic process and social rights [...] Promoting the adoption of AI by the public sector [...for an...] An ecosystem of excellence". In the field of cultural heritage, AI can significantly influence the processes of interpretation and presentation underlying the conservation and enhancement of cultural heritage [Tielden 1957; ICOMOS 2008], playing a leading role through user profiling with repercussions in the methods of storytelling and, above all, the mechanisms of interaction and participation. The interaction between virtual reality, augmented reality, mixed reality and artificial intelligence can lead to direct consequences in the context of the methods of defining and declining experiences in the context of digital heritage [Brusaporci 2017; Pierdicca et al. 2020].
The paper presents a theoretical–methodological reflection on the concept of smart heritage starting from VR/AR/MR visualizations for cultural heritage, which is based on an experience related to the 3D digital reconstruction of the no longer existing baroque configuration of the Basilica of Collemaggio in L'Aquila (figs. 1, 2) [Brusaporci et al. 2021] [1].

Smart Visualizations

The traditional static approach to 'smart cities', centered on infrastructural networks, has developed in the sense of a cultural dimension, where the concept of 'smart cities' has evolved into that of 'smart places', in particular thanks to participatory declinations. Operationally, 'smartness' requires the integration of 'objects' with sensors and their enrichment with information, so that they can interact with the environment. If the so–called 'Internet of Things' poses problems of a substantially technological nature if applied to contemporary products, when it is addressed to artefacts characterized by historical and aesthetic values, issues of a theoretical–methodological nature arise. These relate both to the image of the work and to the respect for its materiality, testimony to the events and cultures that have taken place over time. Therefore, it follows the need for precise reflections on the methods that can favour the information enrichment of cultural heritage. The well–known principles of documentation, recognisability, reversibility and protection, in particular when interacting with the physicality of the assets – for example with sensors or targets – remain firm. One solution is to interact with the artifact only in the visual field, through temporary and mediated views that enrich it with information. This is the case

Fig. 1. Views of the point cloud of the Basilica of Collemaggio.

of video mapping [Rossi 2013], but above all it is what is offered by augmented reality applications [Ch'ng et al. 2017; Clini et al. 2017], able to automatically recognize what is framed by the camera of the device and to superimpose information of various kinds. This type of experimentation is conducted by the research group of the University of L'Aquila, starting from the INCIPICT project [http://incipict.univaq.it/] integrated with the 5G experimentation, through a proprietary app specially developed for the enhancement of cultural, architectural and urban heritage of L'Aquila [Brusaporci et al. 2019]. The application, which can be used in urban areas of the city and in specific interiors, is implemented to tell the history of monuments and places, also by superimposing in real–time 3D virtual reconstructions of past configurations that no longer exist (figs 3, 4). Specifically, the paper presents the experience dedicated to the Basilica of Collemaggio, the heart of the rite of 'Perdonanza', which was included into the UNESCO Intangible Cultural Heritage Lists in 2019. Furthermore, the AR app opens to lines of research aimed at AI, with for example image recognition, user profiling, prediction and management of contents and interactions [Pierdicca et al. 2020]. Conceptually, the close interaction between real heritage – experienced in its own historical environment – and digital visualization refers to the concept of 'Phygital' [Nolaf 2019] and strengthens its applications in the field of cultural heritage.

The AR App by Univaq

Mobile augmented reality (Mobile AR) is gaining increasing attention from both academia and industry. Hardware–based Mobile AR and App–based Mobile AR are the two dominant platforms. However, hardware–based Mobile AR implementation is known to be costly and lacks flexibility, while the App–based one requires additional downloading and installation in advance and is inconvenient for cross–platform deployment. However, with the improved communication and computation capabilities provided by 5G technologies, a combination of both technologies is growing up in order to support tourists and cultural applications. Furthermore, the emergence of 5G mobile communication networks has the potential to enhance the communication efficiency of Mobile AR dense computing in the MEC approach [2]. Several technological advances have started to enter the landscape of Mobile AR. First, the upcoming 5G networks [Coluccelli et al. 2018] bring new opportunities for Mobile AR. They provide higher bandwidth (0.1~1Gb/s) and lower network delay (1~10ms), which improves the data transmission on mobile networks. Second, the introduction of new characteristics, such as MEC, device–to–device (D2D) communication, and network slicing, provides an adaptive and scalable communication mechanism that further provides efficient infrastructures for the deployment and promotion of Mobile AR.
Within the INCIPICT project a MEC based demonstration testbed has been set–up. The system exploits the platform available at the MEC LAB of the University of L'Aquila in order to validate the capabilities of the MEC architecture to support applications dedicated to AR services. The MEC LAB provides a complete and customizable network environment

Fig. 2. Collemaggio AR app for viewing the baroque configuration that no longer exists.

Fig. 3. Screenshot of the Collemaggio AR application: reconstruction of the baroque ceiling and superimposition with the current configuration.

and consists of 3 nodes distributed in the city of Aquila. In the University hub, more than 15 physical servers are available and interconnected using optical and wireless technologies to provide heterogeneous connectivity between nodes up to 10Gbps per network segment. The laboratory hosts also a 5G radio access network and a core network to implement network slicing with guaranteed performance on a common physical infrastructure and it is used to perform edge computing experiments. The availability of distributed computing infrastructures in the city allows the experimentation of the orchestration of virtual services in metropolitan networks required by the AR services.

Moreover, a mobile app based on Apple's ARKit has been developed in order to evaluate service. In order to exploit the system some 3D models were created in different sizes. AR was made by the developed application available for 5G smartphones. All 3D models were stored into the MEC platform and accessed by the 5G network minimizing the latency and with a very high throughput in order to provide the best user experience. Once available within the app a user can browse the 3D model using the device camera.

Conclusion

The examples offered by Google and Amazon to all users highlight how mixed reality applications are and will be increasingly widespread. Therefore, it is believed that the analysis of the possibilities offered in the field of knowledge, conservation and enhancement of cultural heritage is of great importance. The experiment presented is only a first step within a line of research dedicated to the study of architectural heritage.

We want to conclude with a general reflection on the digital dimension of the visual in the narration of cultural heritage, starting from the well–known "Uncanny Valley" by Masahiro Mori, that is, his graphs dedicated to the sense of affinity of people towards robots, in relation their resemblance to humans and their ability to move. We could think of updating Mori's reflection by replacing robots with digital visualizations (VR, AR, MR), and the concept of 'movement' by the influence of machine learning, able to simulate our behaviour in an increasingly effective way and to prevent our requests and wishes more and more efficiently. In the current

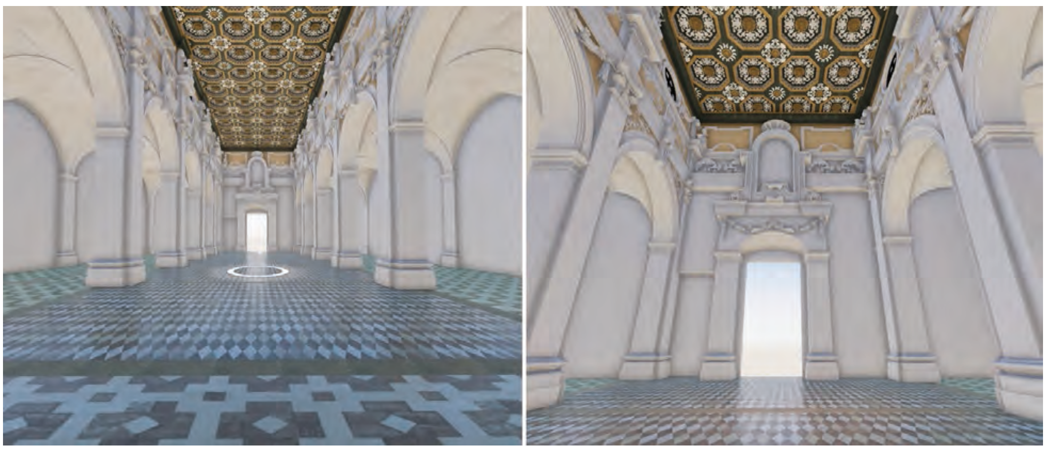


Fig. 4. Views of the reconstruction of the Baroque Collemaggio within the application.

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

Notes

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

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

References

Brusaporci Stefano (2017). *Digital Innovations in Architectural Heritage Conservation: Emerging Research and Opportunities*. Hershey (PA): IGI Global.

Brusaporci Stefano, Graziosi Fabio, Franchi Fabio, Maiezza Pamela (2019). Remediating the Historical City. Ubiquitous Augmented Reality for Cultural Heritage Enhancement. In Luigini Alessandro (ed.). *Proceedings of the 1st International and Interdisciplinary Conference on Digital Environments for Education, Arts and Heritage EARTH 2018*. Cham: Springer, pp. 305-313.

Brusaporci Stefano (2019). The visual bride: representing tangible heritage between digitality and real contents. In Luigini Alessandro, Panciroli Chiara (eds.). *img journal* 01/2019 Manifesto. vol. 01. Alghero: Publica, pp. 74-91.

Brusaporci Stefano, Graziosi Fabio, Franchi Fabio, Maiezza Pamela, Tata Alessandra (2021). Mixed Reality Experiences for the Historical Storytelling of Cultural Heritage. In Bolognesi Cecilia, Villa Daniele (eds.). *From Building Information Modelling to Mixed Reality*. Cham: Springer, pp. 33-46.

Ch'ng Eugene, Cai Yiyu, Thwaites Harold (Eds.) (2017). Special Issue on VR for Culture and Heritage: The Experience of Cultural Heritage with Virtual Reality: Guest Editors' Introduction. In *PRESENCE: Virtual and Augmented Reality*, 26(3), pp. iii-vi.

Clini Paolo, Quattrini Ramona, Frontoni Emanuele, Pierdicca Roberto, Nespeca Romina (2017). Real/not real: pseudo–holography and augmented reality applications for cultural heritage. In *Handbook of Research on Emerging Technologies for Digital Preservation and Information Modeling.* Hershey (PA): IGI Global, pp. 201-227.

Coluccelli Gabriella, Loffredo Vincenzo, Monti Luca, Spada Maria Rita, Franchi Fabio, Graziosi Fabio (2018). 5G Italian MISE Trial: Synergies Among Different Actors to Create a “5G Road”. In *2018 IEEE 4th International Forum on Research and Technology for Society and Industry (RTSI)*. Marsiglia: Institute of Electrical and Electronics Engineers (IEEE) Publisher, pp. 1-4.

Floridi Luciano (ed.) (2015). *The Onlife Manifesto. Being Human in a Hyperconnected Era*. Cham: Springer.

ICOMOS (2008). Charter for the Interpretation and Presentation of Cultural Heritage Sites. http://icip.icomos.org/downloads/ICOMOS_Interpretation_Charter_ENG_04_10_08.pdf (15 January 2021).

Mori Masahiro (1970). Bukimi no tani – The uncanny valley. (K. F. MacDorman & T. Minato, Trans.). *Energy,* 7(4), 33-35. https://web.ics.purdue.edu/~drkelly/MoriTheUncannyValley1970.pdf (15 January 2021).

Nolaf Eslam (2019). Phygital Heritage. Communicating Built Heritage Information through the Integration of Digital Technology into Physical Reality. PhD Thesis, KU Leuven.

Pierdicca Roberto, Paolanti Marina, Frontoni Emanuele, Baraldi Lorenzo (2020). AI4AR: An AI–Based Mobile Application for the Automatic Generation of AR Contents. In De Paolis Lucio Tommaso, Bourdot Patrick (eds.). *Augmented Reality, Virtual Reality, and Computer Graphics. AVR 2020. Lecture Notes in Computer Science*, vol. 12242. Cham: Springer.

Rossi Daniele (2013). Smart architectural models. Spatial projection based augmented mock–up. In Addison Alonzo C., Guidi Gabriele, De Luca Livio, Pescarin Sofia (eds.). *2013 Digital Heritage International Congress*, vol. 2. Marsiglia: Institute of Electrical and Electronics Engineers (IEEE) Publisher.

Schafer D. Paul (2014). *The Age of Culture*. Oakville (ON): Rock's Mills Press.

Tielden Freeman (1957). *Interpreting Our Heritage*. Chapel Hill: University of North Carolina Press.

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

 Isbn 9788835125280

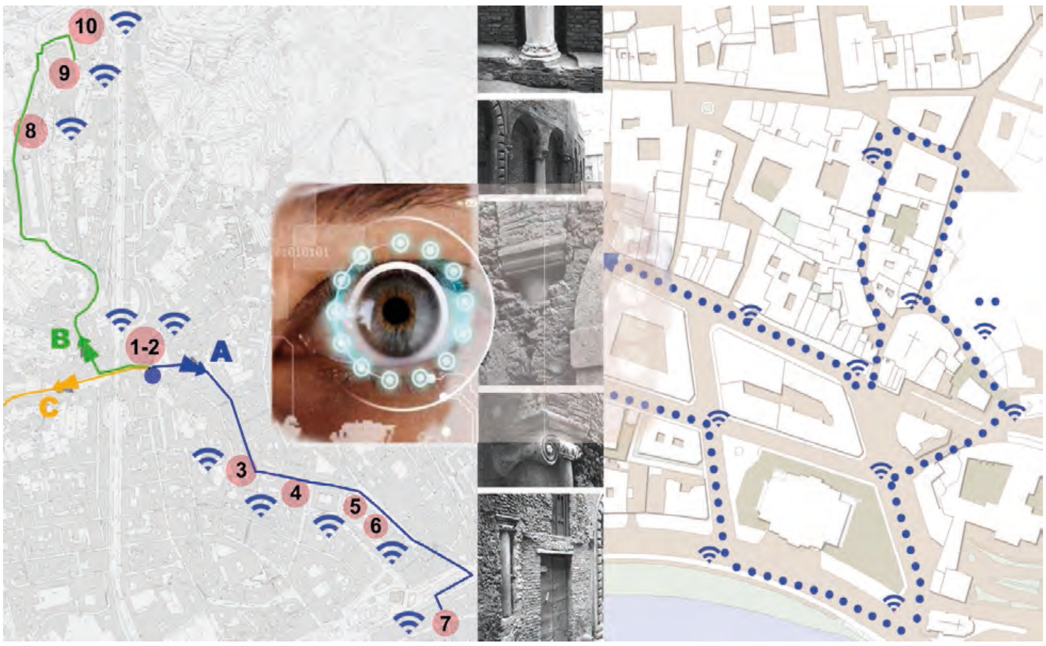
Advanced Practices of Augmented Reality: the Open Air Museum Systems for the Valorisation and Dissemination of Cultural Heritage

Gerardo Maria Cennamo

Abstract

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

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



doi.org/10.3280/oa-686.19

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

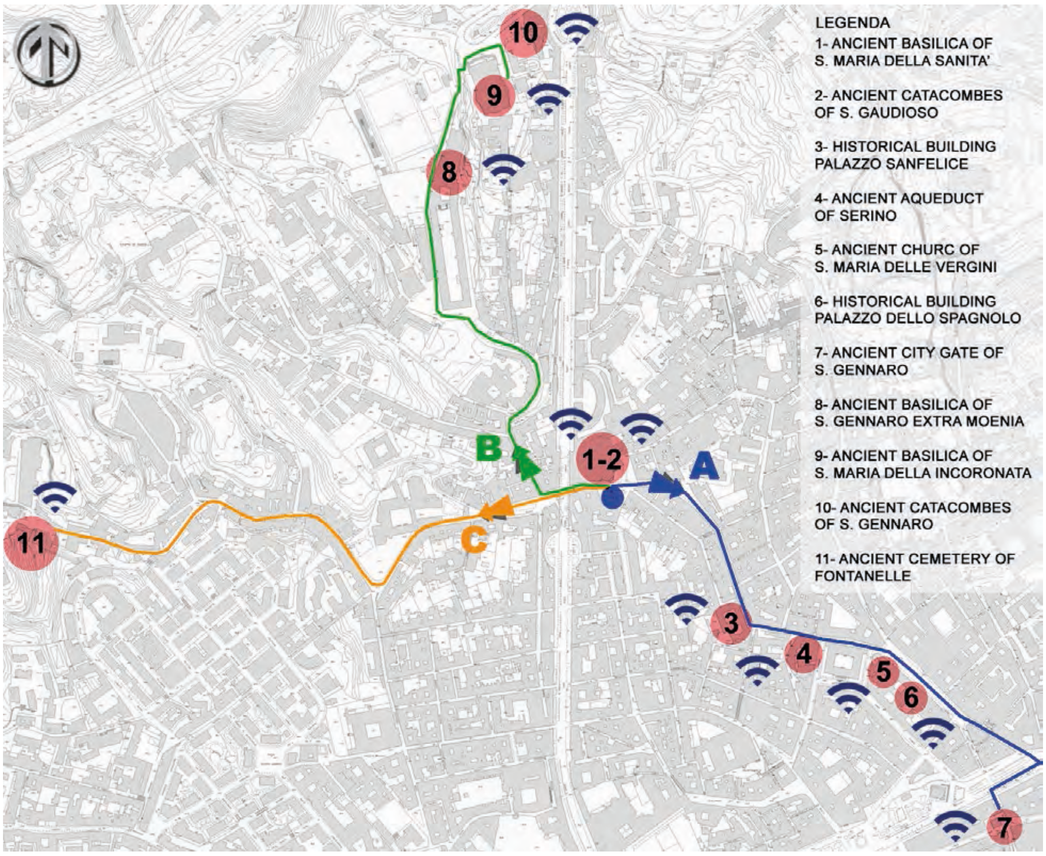


Fig. 1. Open air museum: experiment of immersive AR path, Naples Rione Sanità

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

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

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

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

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

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

Conclusion

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

Notes

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

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

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

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

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

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

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

References

Cennamo Gerardo Maria (2018). Heritage valorisation strategies through development of open–air territorial museum districts. The role of the representation's instruments to learning through dynamic images. In Salerno, R.ossella (ed.) *Rappresentazione Materiale/Immateriale,* Roma: Gangemi Editore International.

Cimatti Felice (2000). L*a scimmia che parla. Linguaggio, autocoscienza e libertà nell'animale umano*. Torino: Bollati Boringhieri.

Forte Maurizio (2004). Realtà virtuale, beni culturali e cibernetica: un approccio ecosistemico. In *Archeologia e Calcolatori,* 15, pp. 423-448.

Pecchinenda Gianfranco (2003). *Videogiochi e cultura della simulazione*. Roma–Bari: Editori Laterza.

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

Isbn 9788835125280

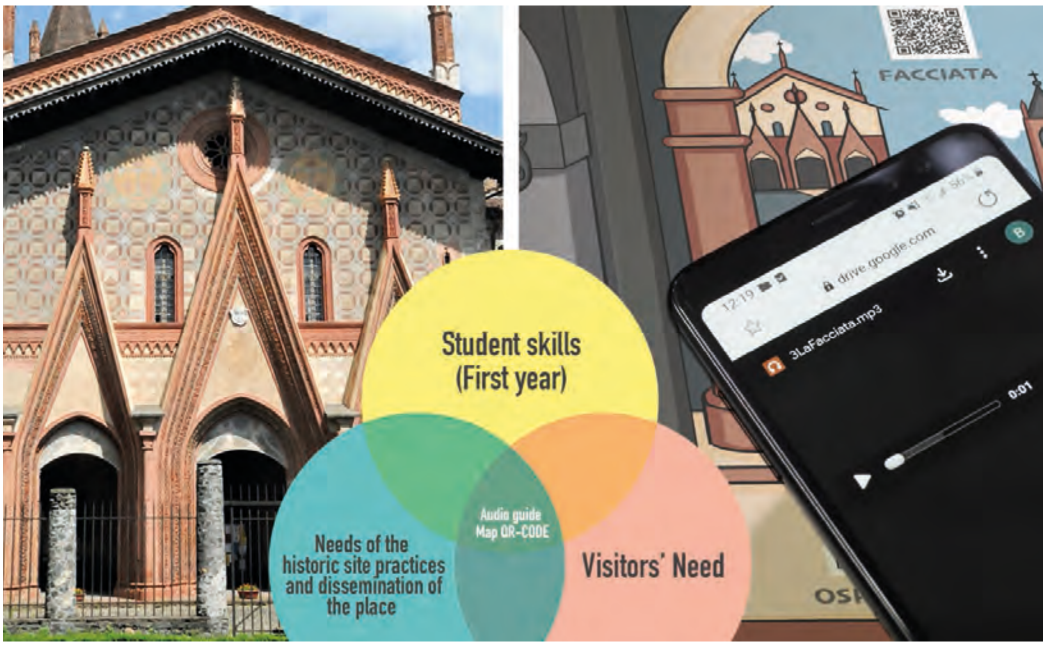
The Use of AR Illustration in the Promotion of Heritage Sites

Serena Fumero
Benedetta Frezzotti

Abstract

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

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



doi.org/10.3280/oa-686.20

Goals and Methodology

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

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

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

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

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

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

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

Discussion

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

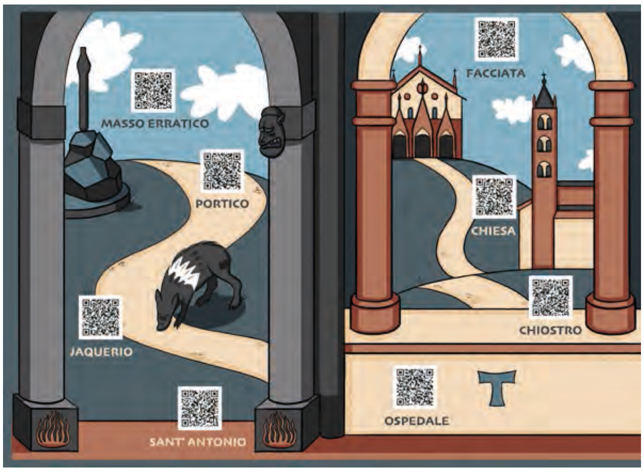


Fig. 2. The first map selected for testing.

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

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

Conclusions

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

Acknowledgements

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

Notes

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

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

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

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

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

References

Bertea Cesare (1923). *Sant'Antonio di Ranverso ed Avigliana*. Torino: Stabilimento tipografico Ajani e Canale.

Devoti Chiara, Naretto Monica (2010). *Ordine e Sanità. Gli ospedali mauriziani tra XVIII e XX secolo: storia e tutela*. Torino: Celid.

Gritella Gianfranco (2001). *Il colore del gotico. I restauri della precettoria di Sant'Antonio di Ranverso.* Savigliano: L'Artistica Editrice.

Griseri Andreina (1966). *Jaquerio e il Realismo Gotico in Piemonte*. Torino: F.lli Pozzo Editore.

Mandarano Nicolette (2019). *Musei e media digitali*. Roma: Carocci Editore.

Molina Alfonso, Mannino Maria (2016). *Educazione per la vita e inclusione digitale. Strategie innovative per la scuola e la formazione degli adulti*. Trento: Erickson.

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

 Isbn 9788835125280

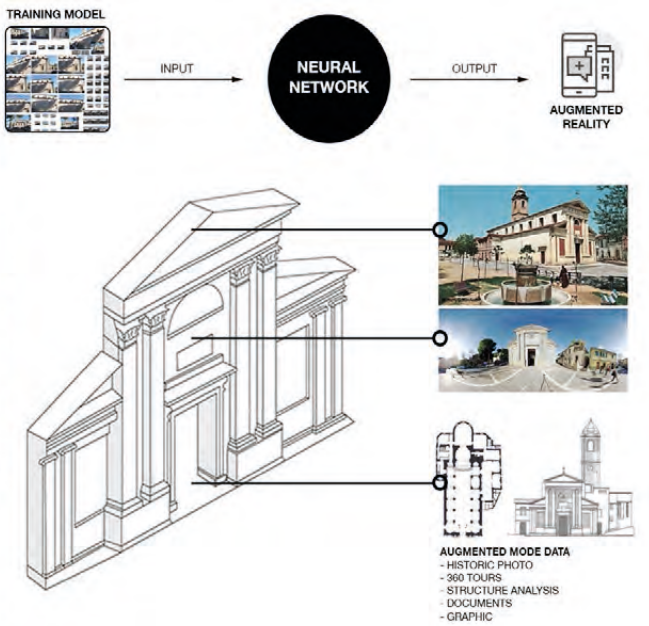
The Sanctuary BVMA in Pescara: AR Fruition of the Pre–Conciliar Layout

Alessandro Luigini
Stefano Brusaporci
Alessandro Basso
Pamela Maiezza

Abstract

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

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



doi.org/10.3280/oa-686.21

Introduction

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

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

Artificial Logic Construction: State of the Art

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

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

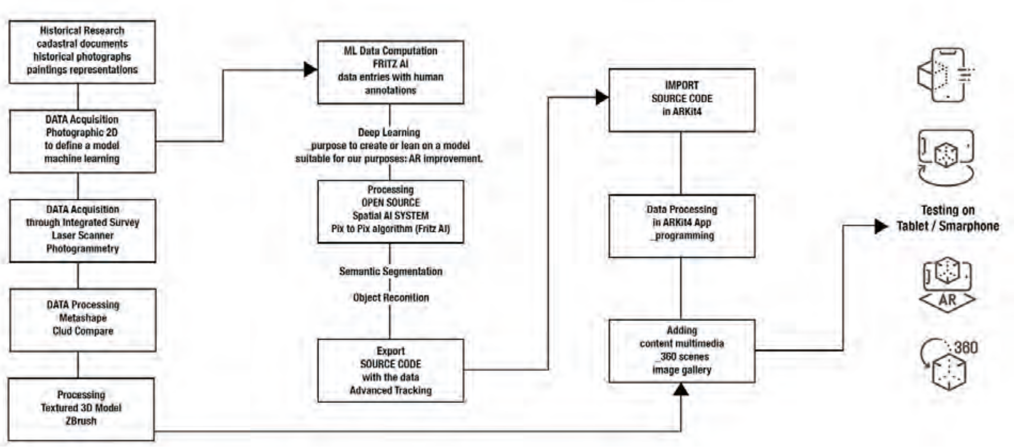


Fig. 2. Complete workflow of the search process: from document search to AR application.

The Application Case Study

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

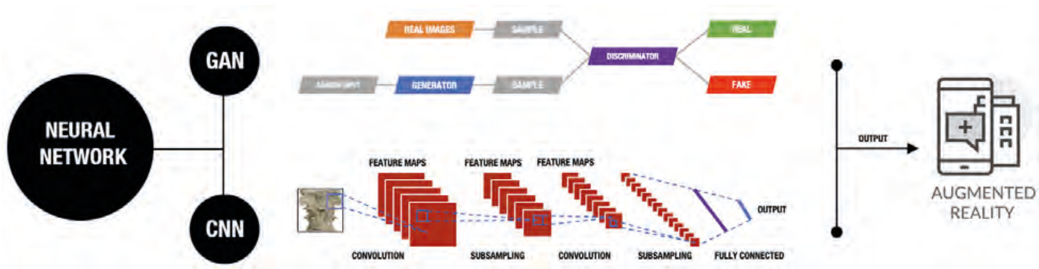


Fig. 3. Synthetic diagram of the functioning of GANs, used for tracking, and CNNs, used for semantic segmentation.

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

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

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

Conclusion

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

References

Asifullah Khan, Anabia Sohail, Umme Zahoora, Aqsa Saeed Qureshi (2020). A Survey of the Recent Architectures of Deep Convolutional Neural Networks. In *Artificial Intelligence Review*, 54, pp. 5455-5516.

Cameron Fiona, Kenderdine Sofia (2007). *Theorizing Digital Cultural Heritage: A Critical Discourse*. Cambridge, MA, USA: MIT Press.

Gordon Cooper (2018). *Computer Vision for Augmented Reality in Embedded Designs*. https://www.edge-ai-vision.com/2018/08/computer-vision-for-augmented-reality-in-embedded-designs/ online view (01 July 2020).

Lampropoulos Georgios, Keramopoulos Euclid, Diamantaras Konstantinos (2020). Enhancing the functionality of augmented reality using deep learning, semantic web and knowledge graphs: A review. In *Visual Informatics*, 4, pp. 32-42.

Luigini Alessandro (ed.). (2019). *Proceedings of the 1st International and Interdisciplinary Conference on Digital Environments for Education, Arts and Heritage EARTH 2018*. Cham: Springer.

Pavlidis George, Koutsoudis Anestis, Arnaoutoglou Fotis, Tsioukas Vassilios, Chamzas Christodoulos (2007). Methods for 3D digitization of Cultural Heritage. In *Journal of Cultural Heritage*, 8 (I), pp. 93-98.

Pescarin Sofia (2016). Digital Heritage into Practice, In *SCIRES–IT*, 6, (1), pp. 1-4.

Trizio Ilaria, Brusaporci Stefano, Luigini Alessandro, Ruggieri Andrea, Basso Alessandro, Maiezza Pamela, Tata Alessandra, Giannangeli Alessandro (2019). Experiencing the Inaccessible. A Framework for Virtual Interpretation and Visualization of Remote, Risky or Restricted Access Heritage Places. In *ISPRS*, 42, pp. 1171-1178.

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

 Isbn 9788835125280

Phygitalarcheology for the Phlegraean Fields

Alessandra Pagliano
Greta Attademo
Anna Lisa Pecora

Abstract

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

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

doi.org/10.3280/oa-686.22

Introduction

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

The Phigital Archeology Project

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

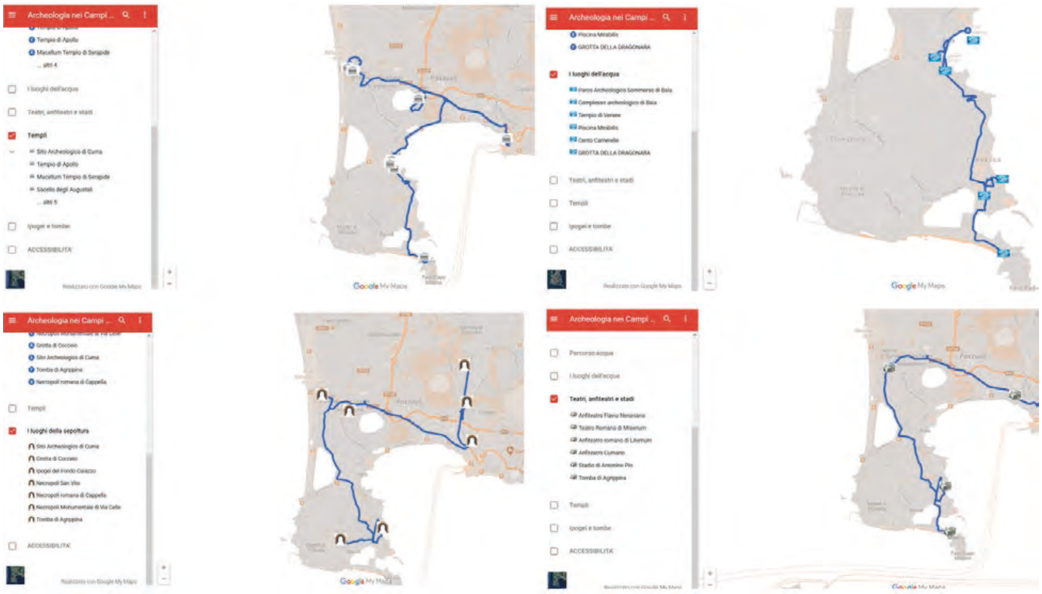


Fig. 1. The four thematic routes for the Archaeological Park of Phlegraean Fields: Temples; Water places; Burial places; Theaters, amphitheaters and stadiums.

Analogical and Digital Augmented Reality

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

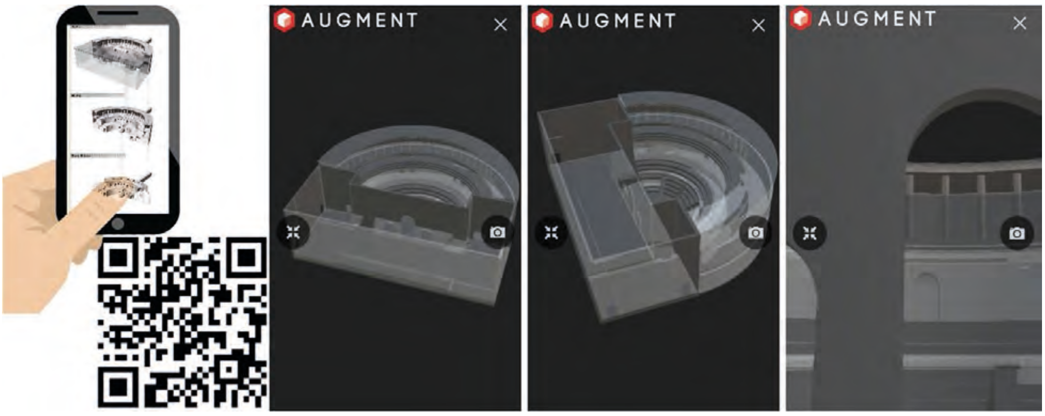


Fig. 2. Digital model of the 'Sepolcro di Agrippina' inserted in the Augment app for Augmented Reality (frame the marker with the scan of the app and the 3d model will appear as in the photo).

Fig. 3. Example of analogical augmented reality.

Conclusions

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

References

Annecchino Raimondo (2004). Bauli–Bacoli. Note storiche. Rist. In Giamminelli Raffaele (ed.). *La 'Collezione Flegrea' di Raimondo Annecchino.* Napoli: Adriano Gallina Editore.

Beloch Karl Julius (1989). *Storia e topografia della Napoli antica e dei suoi dintorni.* Napoli: Bibliopolis. Original: Campanien Gesuchite und Topographie des antiken Neapel un seiner Ungebung. II ed. Breslau: Morgenstern.

Catuogno Raffaele, Porfiri Francesca, Tacchi Gaia Lisa (2017). Survey for the enhancement of the archaeological sites of the Phlegraean Fields: the "Agrippina Sepulchre" in Bacoli. In *IMEKO International Conference on Metrology for Archaeology and Cultural Heritage*. Lecce: Curran Associates Inc., pp. 499-503.

Diedrich Lisa, Lee Gini. Braae Ellen (2014). The Transect as a Method for Mapping and Narrating Water Landscapes: Humboldt's Open Works and Transareal Travelling. In *NANO: New American Notes Online*, 6, pp. 3-15.

Di Liello Salvatore (2005). *Il paesaggio nei Campi Flegrei. Tra realtà e metafora*. Napoli: Electa.

Gianolio Simone (ed.) (2013). *Archeologia Virtuale: comunicare in digitale*. Roma: Espera.

Iaconesi Salvatore, Persico Oriana (2015). Il Terzo Infoscape. Dati, informazioni e saperi nella città e nuovi paradigmi di interazione urbana. In Arcagni Simone (ed.). *I media digitali e l'interazione uomo–macchina*. Roma: Aracne Editore, pp. 139-168.

Iaconesi Salvatore, Persico Oriana (2017). *Digital Urban Acupuncture. Human Ecosystems and the Life of Cities in the Age of Communication, Information and Knowledge*. Berlino: Springer.

Maiuri Amedeo (1995). Il teatro–ninfeo detto "Sepolcro di Agrippina". In *Anthemon. Scritti in onore di C. Anti*. Firenze, pp. 263–271.

McGee Carrie, Rosenberg Francesca (2014). Art Making as Multisensory Engagement. Case Studies from The Museum of Modern. In Levent Nina, Pascual–Leone Alvaro (eds.). *The Multisensory Museum: Cross–Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space*. Lanham (MD): Rowman & Littlefield Publishers, pp. 29-44.

Pagliano Alessandra (2015). Il teatro perduto. Conoscenza e valorizzazione dei beni archeologici sepolti nel territorio di Miseno. In Giovannini Massimo, Di Luggo Antonella, Sacchi Livio, Gambardella Carmine (eds.). *Spazi e culture del mediterraneo 4. Costruzione di un atlante del patrimonio culturale del mediterraneo*. Napoli: La scuola di Pitagora editrice, pp. 215-229.

Pagliano Alessandra (2017). Strategie comunicative per la valorizzazione dei beni culturali: la realtà aumentata per il Sacello degli Augustali a Miseno/ Communcative strategies for the enhancement of cultural heritage: Augmented Reality for the Sacellum of Augustales in Misenum. In *Territori e frontiere della rappresentazione/ Territories and frontiers of representation.* Roma: Gangemi editore International, pp. 555-564.

Volpe Giuliano (2013). Archeologia, paesaggio e società al tempo della crisi: tra conservazione e innovazione, in Archeologia pubblica al tempo della crisi. In Parello Maria Concetta, Rizzo Maria Serena (eds.). *Atti delle Giornate gregoriane*. VII edizione, pp. 183-191.

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

 Isbn 9788835125280

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

Andrea Rolando
Domenico D'Uva
Alessandro Scandiffio

Abstract

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

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

doi.org/10.3280/oa-686.23

Introduction

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

Case Study

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

Methodology

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

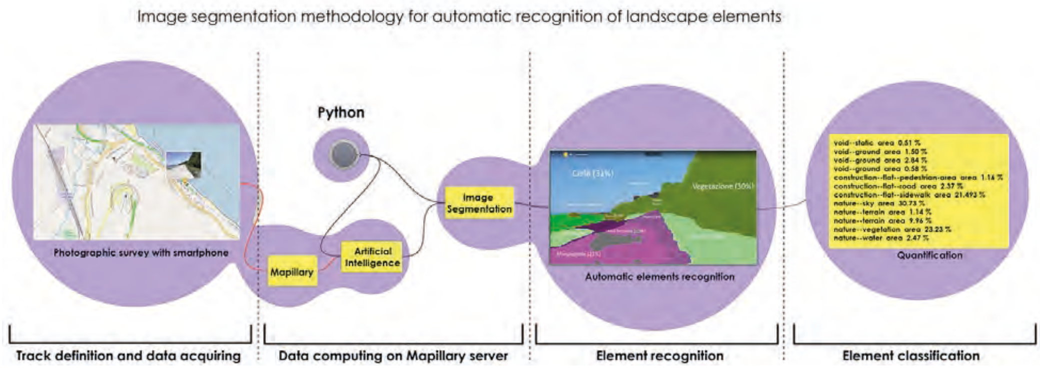


Fig. 1. Workflow of the Image segmentation methodolgy for automatic recognition of landscape elements

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

Outcomes

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

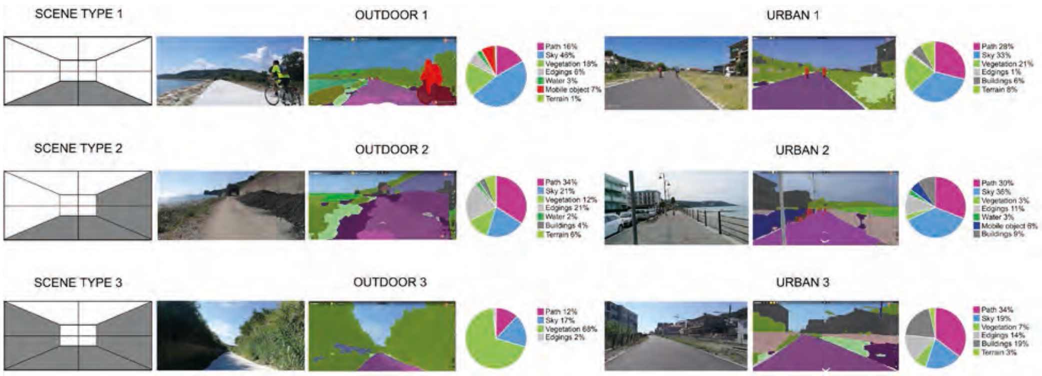


Fig. 2. Comparative table of landscape features along the "via verde della Costa dei Trabucchi" greenway.

Conclusion and Future Research Developments

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

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

Acknowledgments

This work has been carried on within the activities of the E–scapes research group (www.e–scapes.polimi.it directed by A. Rolando) and the Territorial Fragilities Program – MapFrag group (www.eccellenza.dastu.polimi.it) of the Department of Architecture and Urban Studies.

References

Anguelov Dragomir, Dulong Carole, Filip Daniel, Frueh Christian, Lafon Stéphane, Lyon Richard, Ogale Abhijit S. , Vincent Luc, Weaver Josh (2010). Google Street View: Capturing the World at Street Level. In *Computer,* 43(6,) pp. 32-38.

Bianchi Alessandro, D'Uva Domenico, Rolando Andrea, Scandiffio Alessandro (2020). A View from the Track: Measuring Spatial Quality of Slow Mobility Routes. Possible Integration of GIS and Machine Learning Based Methods. In *Connettere Connecting. Un disegno per annodare e tessere/drawing for weaving relationships*. Milano: FrancoAngeli, pp. 2973-2980.

Cao Rui, Zhu Jiasong, Tu Wei, Li Qingquan (2018). Integrating Aerial and Street View Images for Urban Land Use Classification. In *Remote Sensing,* 10, pp. 1-23.

Marcarini Albano, Rovelli Roberto (2018). *Atlante Italiano delle ferrovie in disuso*. Firenze: Istituto Geografico MIlitare.

Porziy Lorenzo , Hofingerz Markus, Ruiz Idoia, Serrat Joan, Rota Bul`oy Samuel, Kontschiedery Peter (2020). Learning Multi–Object Tracking and Segmentation from Automatic Annotations. In *Computer Vision and Pattern Recognition, arXiv.*

Scandiffio Alessandro (2019). Mapping spatial quality of slow routes with a GIS–based method. A comparative assessment of alternative routes. In *International Archives Photogrammetry Remote Sensing Spatial Information Science*, XLII–2/W15, pp.1071-1076.

Warburgy Frederik, Haubergy Søren, Lopez–Antequeraz Manuel, Gargalloz Pau, Kuangz Yubin, Civerax Javier (2020). Mapillary Street–Level Sequences: A Dataset for Lifelong Place Recognition. In Conf. on Computer Vision and Pattern Recognition (CVPR), pp. 1-10.

Zhang Fan, Zhou Bolei, Ratti Carlo (2019). Discovering place–informative scenes and objects using social media photos. In *Royal Society open science*, 6 (3).

Zhang Fan, Zhou Bolei, Liu Liu, Liu Yu, Fung Helene H. , Lin Hui, Ratti Carlo (2018). Measuring human perceptions of a large–scale urban region using machine learning. In *Landscape and Urban Planning*, 180, pp. 148-160.

Zhang Fan, Zuc Jinyan, Huc Mingyuan, Zhub Di, Kangd, Yuhao, Gaod Song, Zhang Yi, Huang Zhou (2020). 101478 Uncovering inconspicuous places using social media check–ins and street view images. In *Computer, Environment and Urban Systems*. Amsterdam: Elsevier.

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

Isbn 9788835125280

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

Giorgio Verdiani
Ylenia Ricci
Andrea Pasquali
Stéphane Giraudeau

Abstract

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

Keywords
virtual reality, augmented reality, photogrammetry, aerialphotogrammetry.

doi.org/10.3280/oa-686.24

Introduction

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

From Site to Virtualization

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

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

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

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

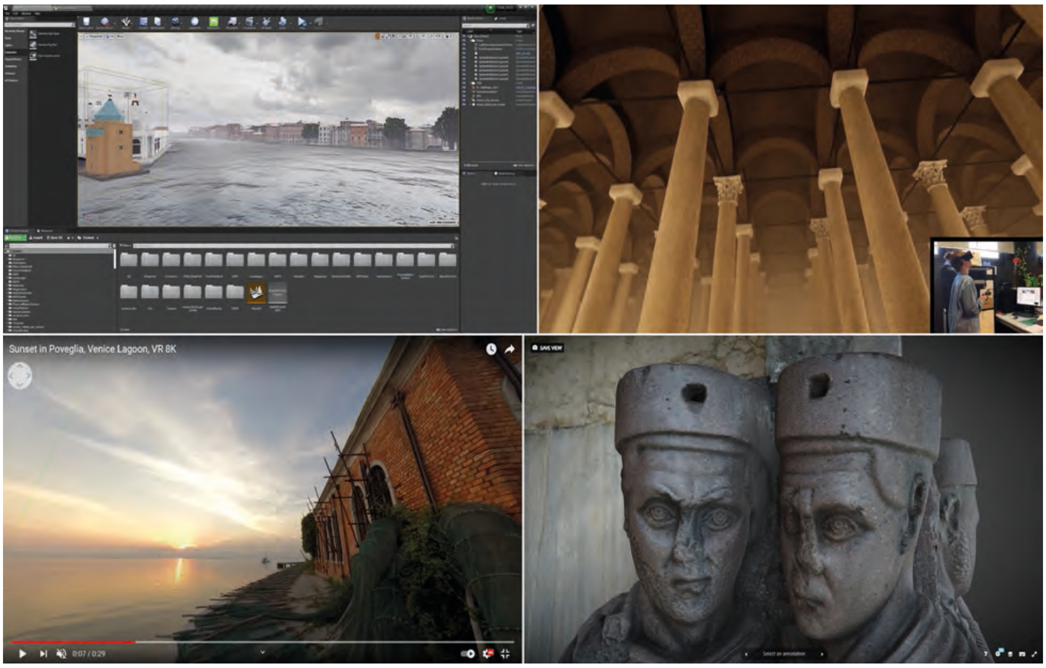


Fig. 1. The theater of the World reconstructed in its virtual space using Epic Games Unreal software, view of the virtual tour in the Basilica Cistern; view from a Panoramic VR shot taken in Poveglia; detail of the Tetrarchs statue in Venice from the sketchfab.com platform.

Case Study Two: The Medusa Protomes Inside the Basilica Cistern

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

Case Study Three: Venice the Tetrarchs Statue

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

Case Study Four: Poveglia, the Abandoned Island

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

Conclusion

The present paper is composed by a sequence of studies with highly diversified contents. As stated in the initial part of the paper, the relationship with the resulting digital products has been accurately analyzed, trying to increase the virtual experience, creating a direct network between the fascination of the stories, the impression coming from the real places and the option offered by the digital solutions.
The desire of experimenting and the will of building specific and effective results is at the base of a research aimed to find efficient solution for presenting parts of the Built and Cultural Heritage in the way they deserve exploiting their best characteristics, creating a specific digital version that is an enhancement or an alternative to the real but that doesn't ask the user to settle for quality and experience, it simply provide a digital approach offering the digital version of that cultural values. The case of the Theater of the World is totally concepted as a dialogue between the location and the virtual reality, increasing the senses' suggestion. In this sense the statue of the Tetrarchs has opposite features, creating interest in something existing as a rich evidence of interactions in the Mediterranean area, the detailed photogrammetry links the real existing with virtual perceptions of knowledge and (maybe) with a desire of completion and investigation about the mysterious and impossible to be told story of its moving from Costantinople to Venice. The other two themes provide the possibility of new points of analysis, which move away from the theme in the studio but still keep close contact with the stimulus coming from the real, such as the introduction of recorded environmental sounds, in the case of the Protomes of Medusa.
This set of experiences have a value that goes far beyond describing the themes and illustrating technologies and methods. They are traces of the experiences and above all provide "a way" about sharing points, suggestions, fascinations, they try to create a specific link between the inner value of stories and places in the continuous tentative of enriching the digital contents with valuable learning occasions. Not only in the will of "capturing" the users, but in the true belief that "Digital Heritage" is an occasion allowing an easier reading and an option for spreading the knowledge of Cultural Heritage, but it need a correct comprehension of these values which is the first real step in creating a constructive system based on a sort of circular flow of attraction –> exploration –> knowledge –> digitalization –> dissemination –> learning –> spreading –> attraction.

References

Brusatin Manlio, Prandi Alberto (eds.) (1982). *Teatro del mondo / Aldo Rossi*. Venezia: Cluva.

Busato Davide, Sfameni Paolo (2018). *Poveglia: L'isola alle origini di Venezia*. Venezia: Lunargento.

Cavallo Federica Letizia, Visentin Francesco (2020). "The world's most haunted island" Ghost narratives and practices around Poveglia, an abandoned island in the Venetian Lagoon. In *Shima Journal*, 14 (1), pp. 194-211.

Dorigo Wladimiro (2004). Spolia marmorei d'oltremare a Venezia (secoli XI-XIV). In *Saggi e memorie di storia dell'arte*, 28, pp. 1-13.

García Carolina Beatriz (2006). Il teatro del mondo: Aldo Rossi (1979-1980). In *DC Papers. Revista de crítica i teoria de l'arquitectura*, 15, pp. 146-149.

Missagia Andrea (2015). *Spolia Costantinopolitani. Il Gruppo dei Tetrarchi a Venezia*. Esposizione seminariale "La piazza di San Marco a Venezia", Storia dell'Arte del Veneto Medievale Sp. – Università Ca' Foscari di Venezia, a.a. 2014/2015, Italy.

Rees Roger (1993). Images and Image: A Re–examination of Tetrarchic Iconography. In *Greece & Rome*, Second Series, 40 (2), pp. 181-200.

Ricci Ylenia, Verdiani Giorgio, Pasquali Andrea (2018). A Petrified Petrifying Eyesight: A Story for the Medusa's heads from Istanbul, Turkey. In *Proceedings of the 23rd International Conference on Cultural Heritage and New Technologies 2018*. CHNT 23.

Verdiani Giorgio, Ricci Ylenia, Pasquali Andrea (2019). Mito, Pietra, Spolia e Storia, Frammenti di indefinito da Costantinopoli a Istanbul. In Conte Antonio, Guida Antonella (eds.), *ReUso Matera Patrimonio in Divenire conoscere valorizzare abitare*. Roma: Gangemi, pp. 1203-1214.

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

 Isbn 9788835125280

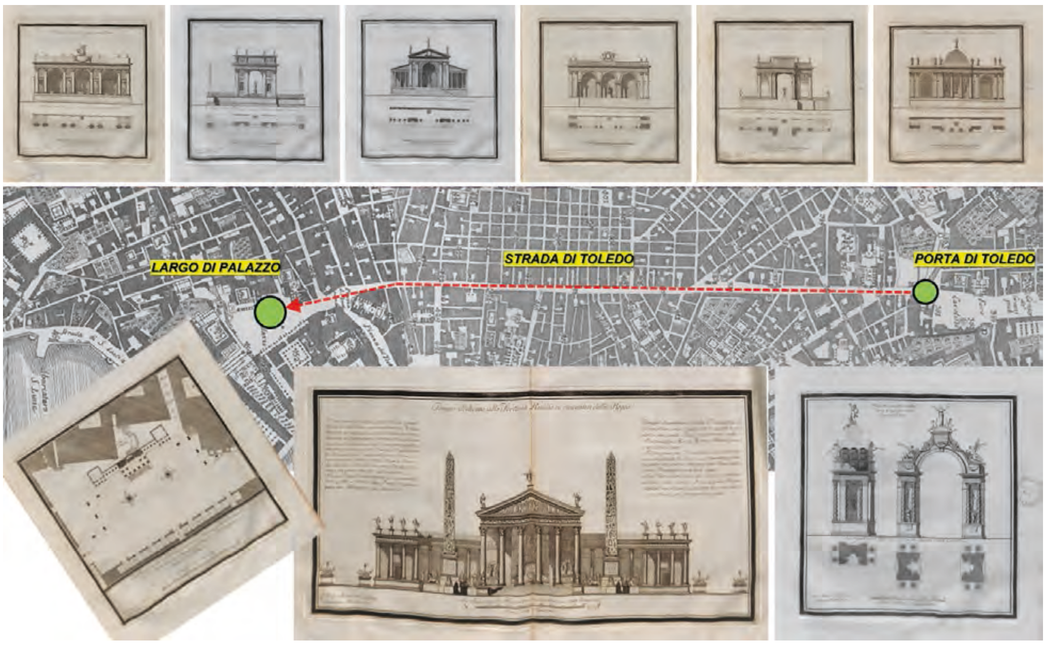
Drawing, Visualization and Augmented Reality of the 1791 Celebration in Naples

Ornella Zerlenga
Vincenzo Cirillo
Massimiliano Masullo
Aniello Pascale
Luigi Maffei

Abstract

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

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



doi.org/10.3280/oa-686.25

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

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

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

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

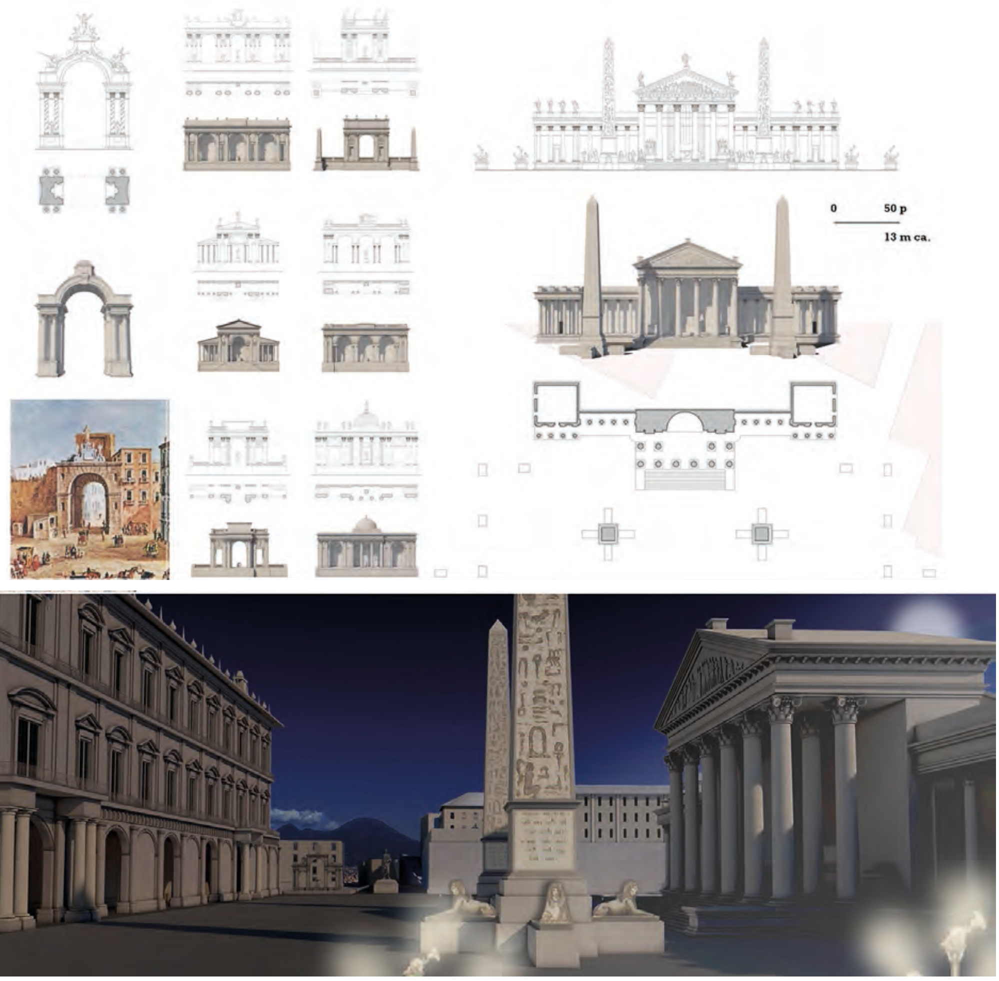


Fig. 1. Above, Entrance Door, Seats and Temple of Fortuna Reduce: plan–altrimetric drawings and 3D modeling; below, visualization of the Temple of Fortuna Reduce in Largo di Palazzo (drawings and graphic elaborations by Pasquale Valentino and Vincenzo Cirillo).

The Prototype of the Application in AR

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

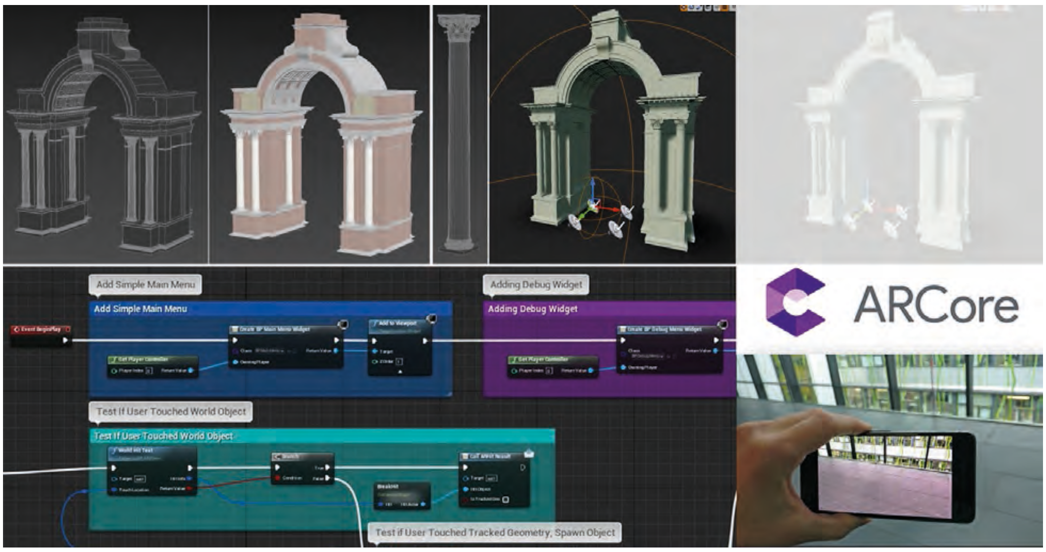


Fig. 2. Above, optimization of the 3D Model and creation of Assets; below, Implementation of the plan recognition system for AR applications (by Aniello Pascale).

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

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

Conclusions

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

Notes

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

References

Cirillo Vincenzo (2017). Riflessioni su disegno e visualizzazione della Fiera del 1738. In *Eikonocity*, 2, II (1), pp. 101-118.

Di Fede Maria Sofia (2005-2006). La festa barocca a Palermo: città, architetture, istituzioni | Baroque Festival in Palermo: City, Architectures and Institutions. In *Espacio, Tiempo y Forma, Serie VII, H.a del Arte, 18-19*, pp. 49-75.

Idee per le pubbliche Feste nel ritorno in Napoli de' Nostri Augusti Sovrani dalla Germania dell'architetto Gaetano Barba, Accademico di merito di S. Luca (1971). Napoli: Gaetano Raimondi.

Isgrò Giovanni (2019). *L'idea del teatro festivo urbano e lo status anomalo dello spettacolo in Sicilia*. http://www.istitutoeuroarabo.it/DM/lidea-del-teatro-festivo-urbano-e-lo-status-anomalo-dello-spettacolo-in-sicilia/ (8 January 2021).

Jacazzi Danila (1995). *Gaetano Barba architetto «neapolitano» 1730-1806*. Napoli: Edizioni Scientifiche Italiane.

Mancini Franco (1997). *Feste e apparati civili e religiosi in Napoli dal viceregno alla capitale*. Napoli: Edizioni Scientifiche Italiane.

Mancini Franco (1980). Il 'trucco' urbano: apparati e scenografie tra finzione e realtà. In *Civiltà del '700 a Napoli 1734-1799.*. Napoli: Edizioni Scientifiche Italiane, pp. 331-333.

Nel felicissimo ritorno degli Augusti Sovrani Ferdinando IV e Maria Carolina d'Austria. Feste Pubbliche della Fedelissima Città di Napoli (1791). Napoli: Giuseppe Maria Porcelli.

Voinea Gheorghe–Daniel, Girbacia Florin, Postelnicu Cristian Cezar, Marto Anabela (2018). Exploring Cultural Heritage Using Augmented Reality Through Google's Project Tango and ARCore. *First International Conference, VRTCH*, pp. 93-106.

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

 Isbn 9788835125280

AR&AI classification and 3D analysis

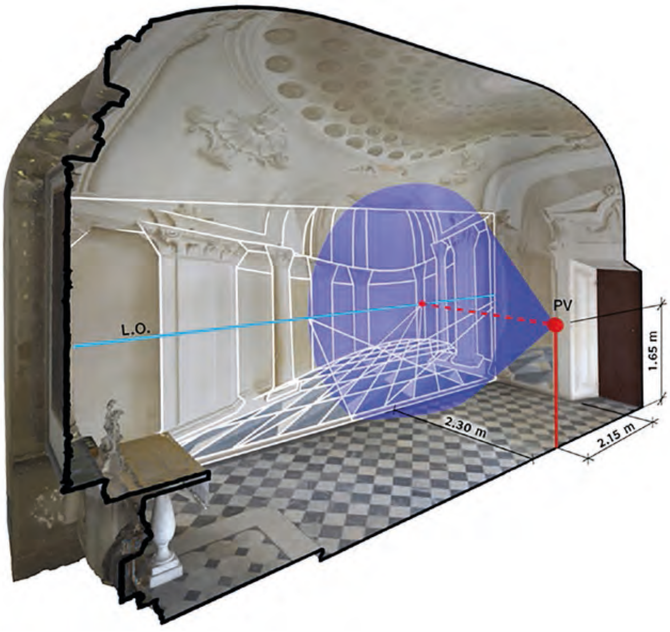
Immersive Technologies for the Museum of the Charterhouse of Calci

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

Abstract

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

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



doi.org/10.3280/oa-686.26

Introduction

Recent studies demonstrate how immersive technologies based on augmented, real, and mixed reality are currently and widely used in the fruition of cultural heritage (Bekele et al. 2018). In the field of fruition of monuments and museal spaces, these technologies provide solutions enabling patrons to view 3D digital models of cultural artifacts and to interact with them in a variety of ways, enhancing their involvement (Trunfio et al. 2021). Most of these applications enjoy continuous evolution in the fields of 3D digital survey, modeling, and graphics. AR applications, virtual reconstructions, video mapping, etc. are, in fact, widely used to enhance visiting experiences, as well as serving as tools for promotion and enhancement of cultural heritage. In Italy, there are several noteworthy cases, such as those of the Virtual Archaeological Museum of Herculaneum, the Egyptian Museum of Turin, and the National Archaeological Museum of Naples, the AR/VR applications at the Baths of Caracalla and the Ara Pacis in Rome, and the video mappings in the Imperial Forums in Rome, to name but a few.
This contribution intends to present the first results of a project aimed at enhancing the tour of the National Museum of the Monumental Charterhouse of Calci using immersive technologies. The project envisaged the definition of a new visit path, modifying the current one and integrating it with immersive experiences of video mapping, VR/AR, sound immersion, information totems, audio–visual supports, and multisensory activities.

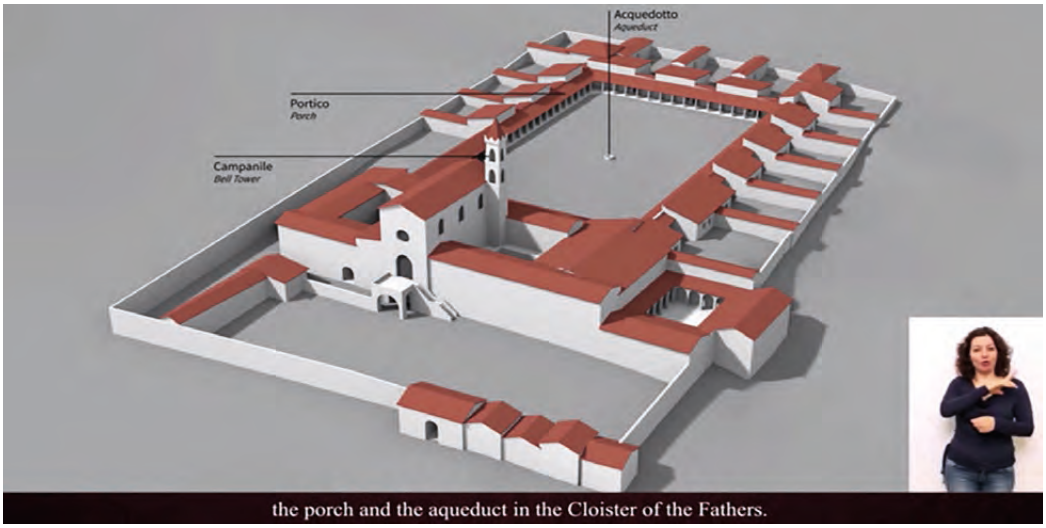


Fig. 1. Frame of the introductive video projected in the Chapel of San Sebastiano (elaborations by A. Fedeli).

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

Founded in 1360 on the slopes of Monte Pisano, the Charterhouse of Pisa in Calci represents one of the most significant monasteries in Tuscany. The charterhouse is the result of several modifications and extensions documented from its founding to the end of the 18th century and reflects the strict rules of the Carthusian Order [Piombanti 1884; Manghi 1911, Giusti & Lazzarini 1993]. It represents an ideal semi–urban 'village' in which hermit and cenobitic life are harmoniously blended. The *correria*, the *coenobium*, and the *desertum* are distributed following the idea of a gradual separation of the fathers from the common life. The large Courtyard of Honor separates the entrance and the *correria* from the *coenobium* and the church; this is placed in a central position emphasizing the compositional axis of the entire complex. On the southern side of the church, there are spaces dedicated to the life of the religious community (minor cloisters, refectory, *colloquium*, and chapter room), the noble guesthouse, and the grand ducal apartments. The northern side boasts several buildings originally used for agricultural activities. The Great Cloister with the cells of Fathers completes the system on the eastern side.
In 1962 the religious community left the Charterhouse of Calci. Since 1972, the complex has hosted the National Museum of the Monumental Charterhouse of Calci, under the control of

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

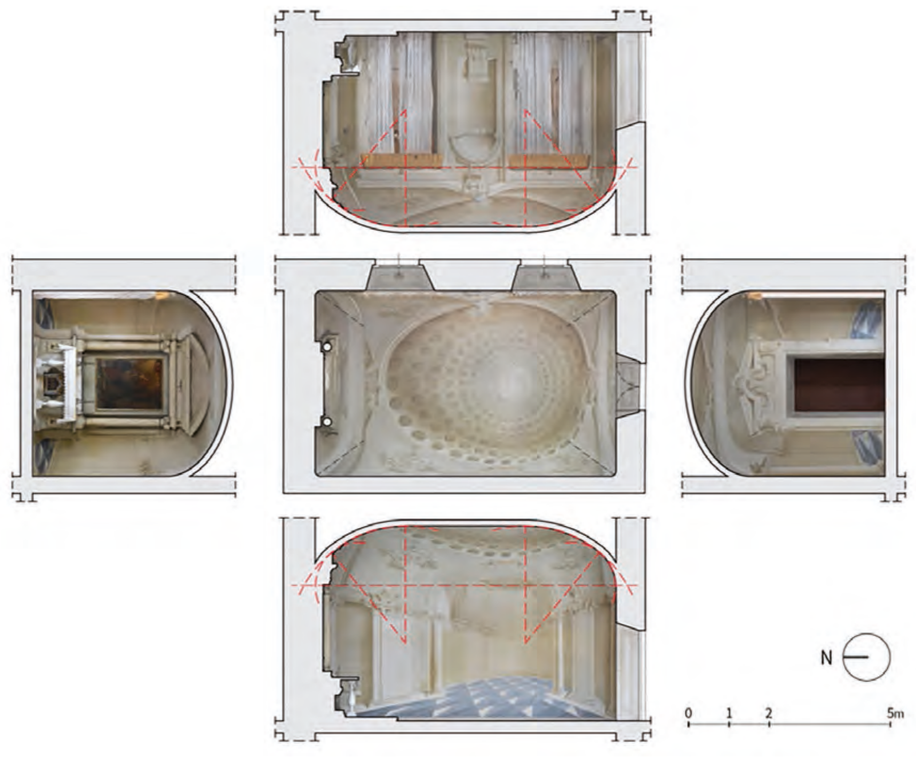


Fig. 2. Orthophotos of the frescoes in the Chapel of St. Anthony (elaborations by A. Fedeli).

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

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

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

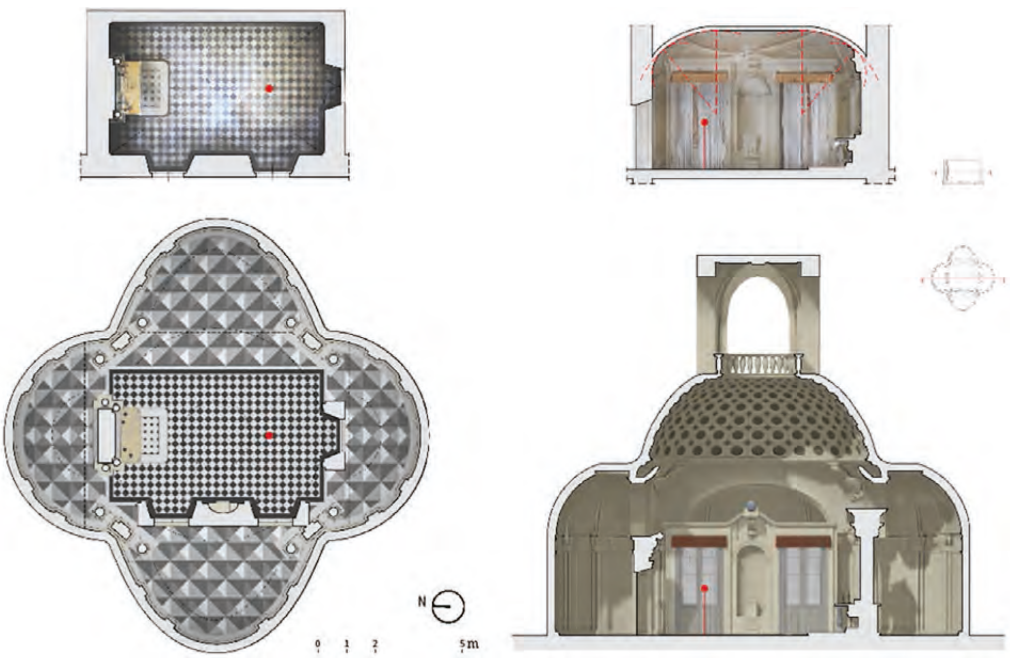


Fig. 3. Comparison between real space – on the top – and illusory one – on the bottom – in the Chapel of Sant'Antonio. Plan and longitudinal section (elaborations by A. Fedeli).

Immersive Experiences at the Museum of the Charterhouse of Calci

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

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

Conclusions

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

Notes

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

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

References

Bekele Mafkereseb, Pierdicca Roberto, Frontoni Emanuele, Malinverni Eva, Gain James (2018). A Survey of augmented, virtual, and mixed reality for cultural heritage. In *Journal on Computing and Cultural Heritage*, 11 (2), pp. 1-36.

Giusti Maria Adriana, Lazzarini Maria Teresa (1993). *La Certosa di Pisa a Calci.* Pisa: Pacini Editore.

Manghi Aristo (1911). *La Certosa di Pisa: storia (1366-1866)* e *descrizione*. Pisa: F. Mariotti.

Piombanti Giuseppe (1884). *La Certosa di Pisa* e *dell'isola di Gorgona*. Livorno: Fabbreschi Editore.

Trunfio Mariapina, Della Lucia Maria, Campana Salvatore, Magnelli Adele (2021). Innovating the cultural heritage museum service model through virtual reality and augmented reality: the effects on the overall visitor experience and satisfaction. In *Journal of Heritage Tourism*, 10, pp. 1-19.

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

 Isbn 9788835125280

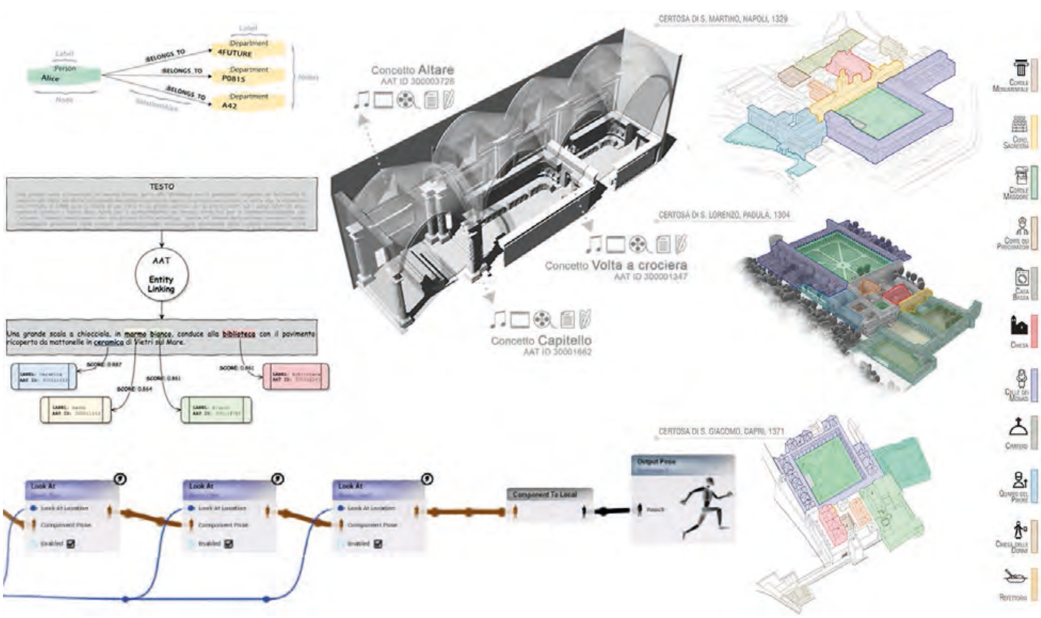
CHROME Project: Representation and Survey for AI Development

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

Abstract

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

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



doi.org/10.3280/oa-686.27

The CHROME Project: Methodology and Procedures

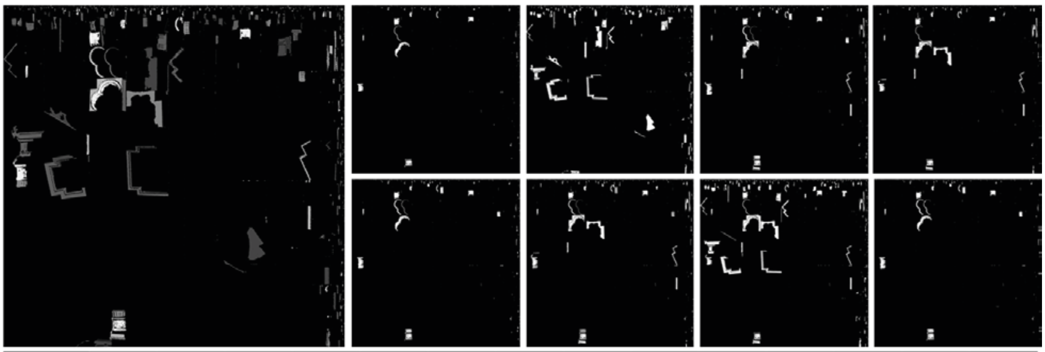
The paper shows the specific results of the PRIN 2015 CHROME Cultural Heritage Resources Orienting Multimodal Experiences, developed around the case studies of the three charterhouses of Campania, with the focus on research activities related to the connections between representation, survey, artificial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

Representation for Semantic Structuring and Knowledge Formalization

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

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

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



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

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

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

From Survey to Development of Artificial Intelligence

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

Results

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

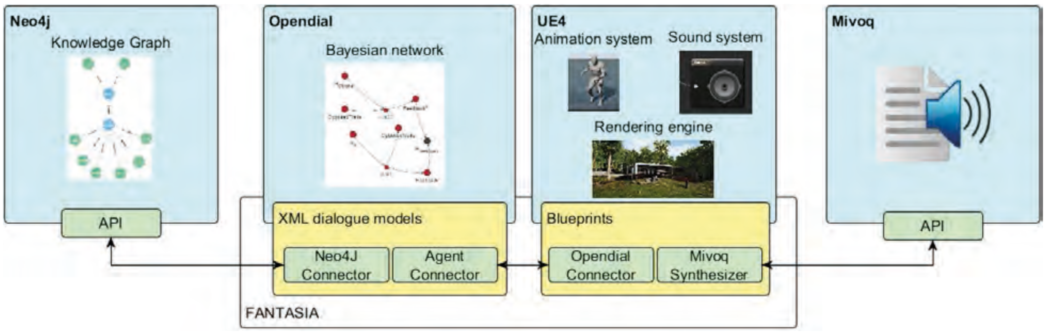


Fig. 2. The original FANTASIA architecture. An updated version was used in this work.

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

Notes

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

References

Cera Valeria (2019). *La significazione digitale dell'elemento architettonico: dal rilievo alla strutturazione semantica dell'architettura.* Napoli: Editori Paparo.

Cera Valeria, Origlia Antonio, Cutugno Francesco, Campi Massimiliano (2018). Semantically Annotated 3D Material Supporting the Design of Natural User Interfaces for Architectural Heritage. In *2018 AVI–CH Workshop on Advanced Visual Interfaces for Cultural Heritage*, 2091, pp. 1-4.

Origlia Antonio, Cutugno Francesco, Rodà Antonio, Cosi Piero, Zmarich Claudio (2019). FANTASIA: a framework for advanced natural tools and applications in social, interactive approaches. In *Multimedia Tools and Applications*, 78 (10), pp. 13613-13648.

Origlia Antonio, Savy Renata, Poggi Isabella, Cutugno Francesco, Alfano Iolanda, D'Errico Francesca, Vincze Laura, Cataldo Violetta (2018). An audiovisual corpus of guided tours in cultural sites: Data collection protocols in the chrome project. In *2018 AVI–CH Workshop on Advanced Visual Interfaces for Cultural Heritage*, 2091, pp. 1-4.

Webber Jim (2012). A programmatic introduction to Neo4j. In *Proceedings of the 3rd annual conference on Systems, programming, and applications: software for humanity.* New York: Association for Computing Machinery, pp. 217-218.

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

 Isbn 9788835125280

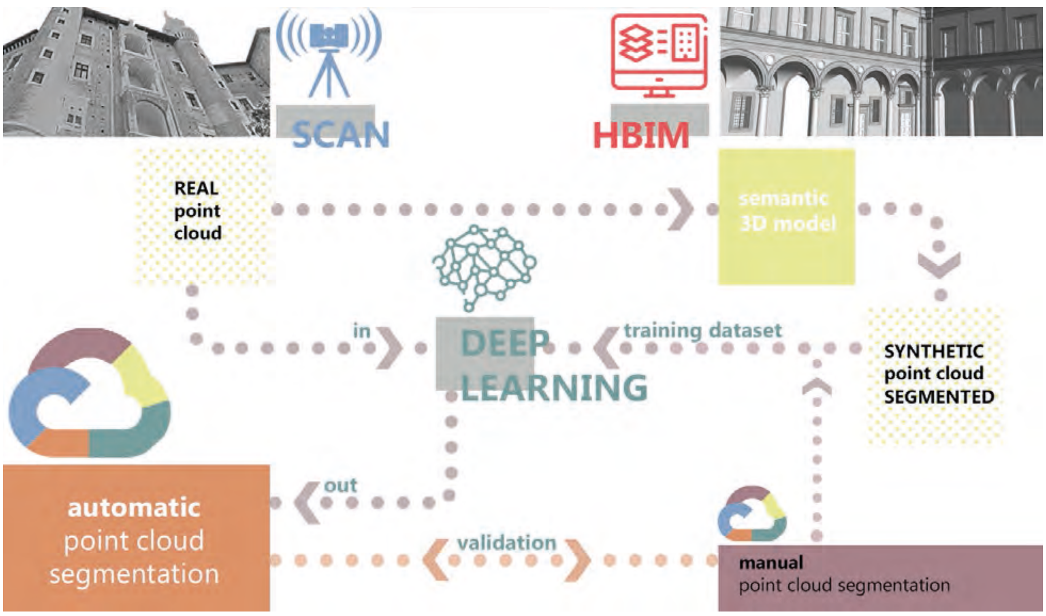
Deep Learning for Point Clouds Classification in the Ducal Palace at Urbino

Paolo Clini
Roberto Pierdicca
Ramona Quattrini
Emanuele Frontoni
Romina Nespeca

Abstract

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

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



doi.org/10.3280/oa-686.28

Introduction

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

State of the Art

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

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

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

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

Semantic Segmentation by Deep Learning Approach

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

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

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

Conclusions

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

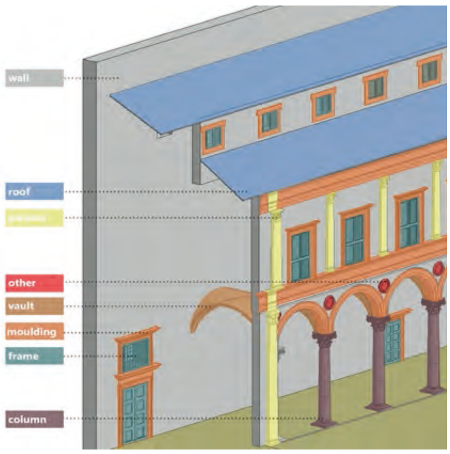


Fig. 2. Point clouds of the Ducal Palace at Urbino.

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

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

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

References

Bertacchi Silvia, Al Jawarneh Isam Mashhour, Apollonio Fabrizio Ivan, Bertacchi Gianna, Cancilla Michele, Foschini Luca, Grana Costantino, Martuscelli Giuseppe, Montanari Rebecca (2018). SACHER Project. In *Proceedings of the 4th EAI International Conference on Smart Objects and Technologies for Social Good – Goodtechs '18*. New York: ACM Press, pp. 283-288.

Clini Paolo, Quattrini Ramona, Bonvini Paolo, Nespeca Romina, Angeloni Renato, Mammoli Raissa, Dragoni Aldo Franco, Morbidoni Christian, Sernani Paolo, Mengoni Maura (2020). Digit (al) isation in Museums: Civitas Project–AR, VR, Multisensorial and Multiuser Experiences at the Urbino's Ducal Palace. In *Virtual and Augmented Reality in Education, Art, and Museums*. Hershey: IGI Global, pp. 194-228.

Clivaz Claire (2020). Digitized and Digitalized Humanities: Words and Identity. In *Atti del IX Convegno Annuale AIUCD. La svolta inevitabile: sfide e prospettive per l'Informatica Umanistica*. Milano: University del Sacre Cuore, pp. 67-73.

Iadanza Ernesto, Maietti Federica, Ziri Anna Elisabetta, Di Giulio Roberto, Medici Marco, Ferrari Federico, Bonsma Paul, Turillazzi Beatrice (2019). Semantic Web Technologies Meet Bim for Accessing and Understanding Cultural Heritage. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII–2/W9 (2/W9), pp. 381-388.

Morbidoni Christian, Pierdicca Roberto, Paolanti Marina, Quattrini Ramona, Mammoli Raissa (2020a). Learning from synthetic point cloud data for historical buildings semantic segmentation. In *Journal on Computing and Cultural Heritage*. 13 (4), pp. 1-16.

Morbidoni Christian, Pierdicca Roberto, Quattrini Ramona, Frontoni Emanuele (2020b). Graph CNN with radius distance for semantic segmentation of historical buildings TLS point clouds. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLIV–4/W1–2020, pp. 95-102.

Nespeca Romina (2018). Towards a 3D digital model for management and fruition of Ducal Palace at Urbino. An integrated survey with mobile mapping. In *SCIRES–IT – SCIentific RESearch and Information Technology*, 8 (2), pp. 1-14.

Pierdicca Roberto, Paolanti Marina, Matrone Francesca, Martini Massimo, Morbidoni Christian, Malinverni Eva Savina, Frontoni Emanuele, Lingua Andrea Maria (2020). Point cloud semantic segmentation using a deep learning framework for cultural heritage. In *Remote Sensing*. 12 (6), p. 1-23.

Rechichi Fabrizio, Mandelli Alessandro, Achille Cristiana, Fassi Francesco (2016). Sharing High–Resolution Models and Information on Web: The Web Module of Bim3DSG System. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. XLI–B5, pp. 703-710.

Teruggi Simone, Grilli Eleonora, Russo Michele, Fassi Francesco, Remondino Fabio (2020). A Hierarchical Machine Learning Approach for Multi–Level and Multi–Resolution 3D Point Cloud Classification. In *Remote Sensing*. 12 (16), pp. -27.

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

 Isbn 9788835125280

Automated Modelling of Masonry Walls: a ML and AR Approach

Pierpaolo D'Agostino
Federico Minelli

Abstract

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

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

doi.org/10.3280/oa-686.29

Introduction

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


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

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

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

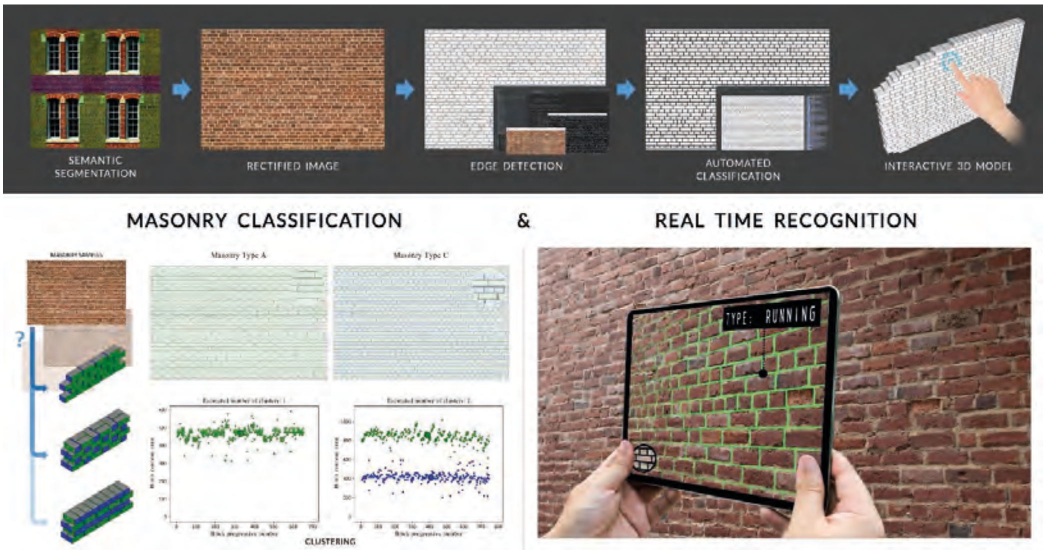


Fig. 2. Layout of the proposed workflow.

Methodology

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

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

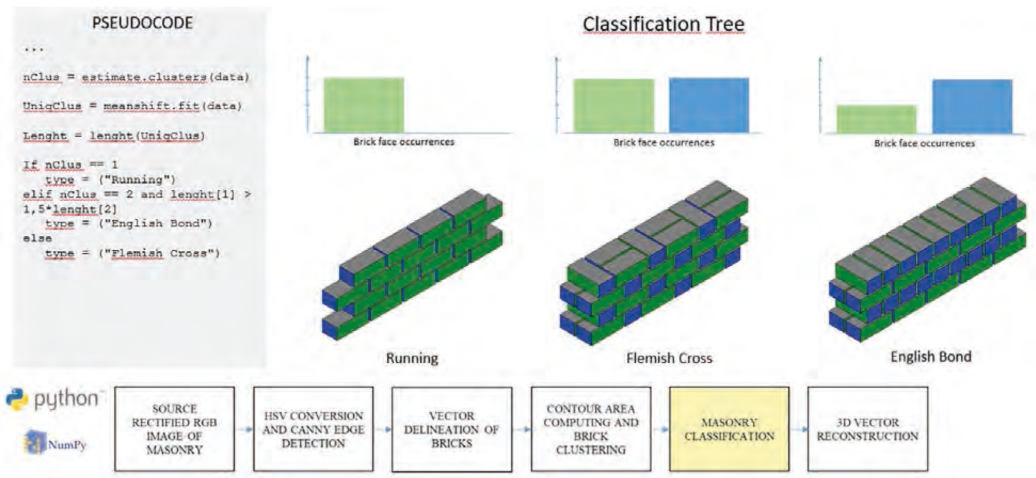


Fig. 3. The masonry classification process: brick face occurences detection to define the wall textures.

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

Conclusions

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

References

Czerniawski Thomas, Leite Fernanda (2020). Automated digital modeling of existing buildings: A review of visual object recognition methods. In *Automation in Construction*. Elsevier, 113, pp. 103-131.

D'Agostino Pierpaolo, Minelli Federico (2020). Automated image–based detection and vectorization of coursed masonry for parametric modeling of building envelope. In Marchiafava Veronica, Picollo Marcello (eds). *Colour and Colorimetry Multidisciplinary Contributions*. Milano: Gruppo del Colore – Associazione Italiana Colore, pp. 43-50.

Musialski Przemyslaw, Wonka Peter, Aliaga Daniel G., Wimmer Michael, Van Gool Luc, Purgathofer Werner (2013). A survey of urban reconstruction. In *Computer Graphics Forum*, 32 (6), pp. 146-177.

Patraucean Viorica, Armeni Iro, Nahangi Mohammad, Yeung Jamie, Brilakis Ioannis, Haas Carl (2015). State of research in automatic as–built modelling. In *Advanced Engineering Informatics*, 29 (2), pp. 162-171.

Zhu Wenhua, Wang Dexian, Eynard Benoit, Bricogne Matthieu, Remy Sebastien (2016). Procedural approach for 3D modeling of city buildings. In *IFIP Advances in Information and Communication Technology*, 467, pp. 137-148.

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

 Isbn 9788835125280

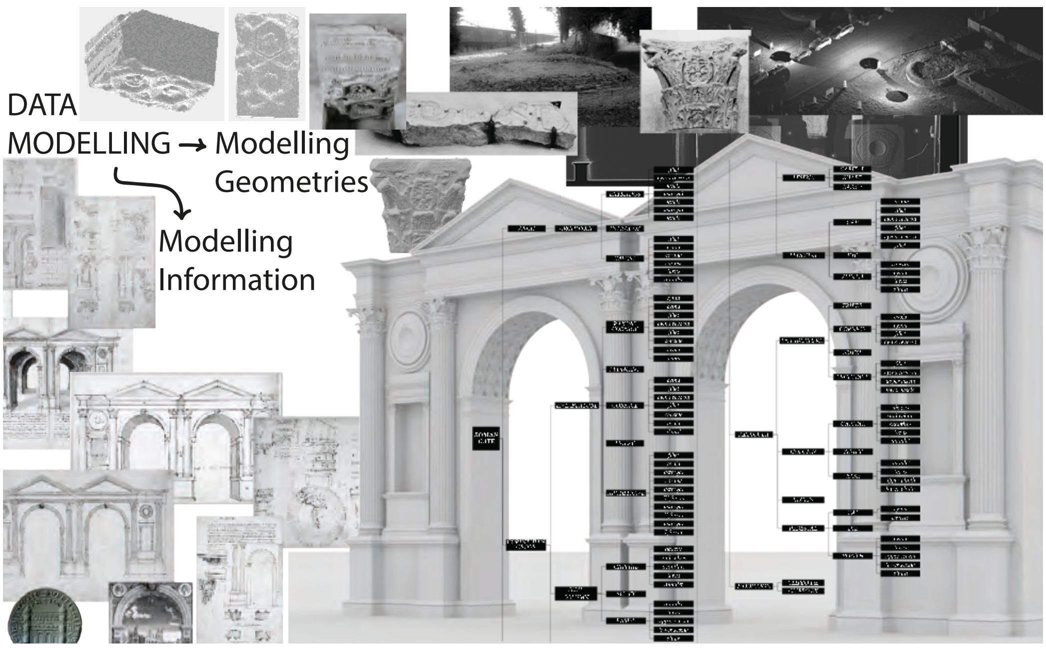
Data Modelling in Architecture: Digital Architectural Representations

Elisabetta Caterina Giovannini

Abstract

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

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



doi.org/10.3280/oa-686.30

The Complexity of Digital Architectural Representations

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

Knowledge Representation in Architecture

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

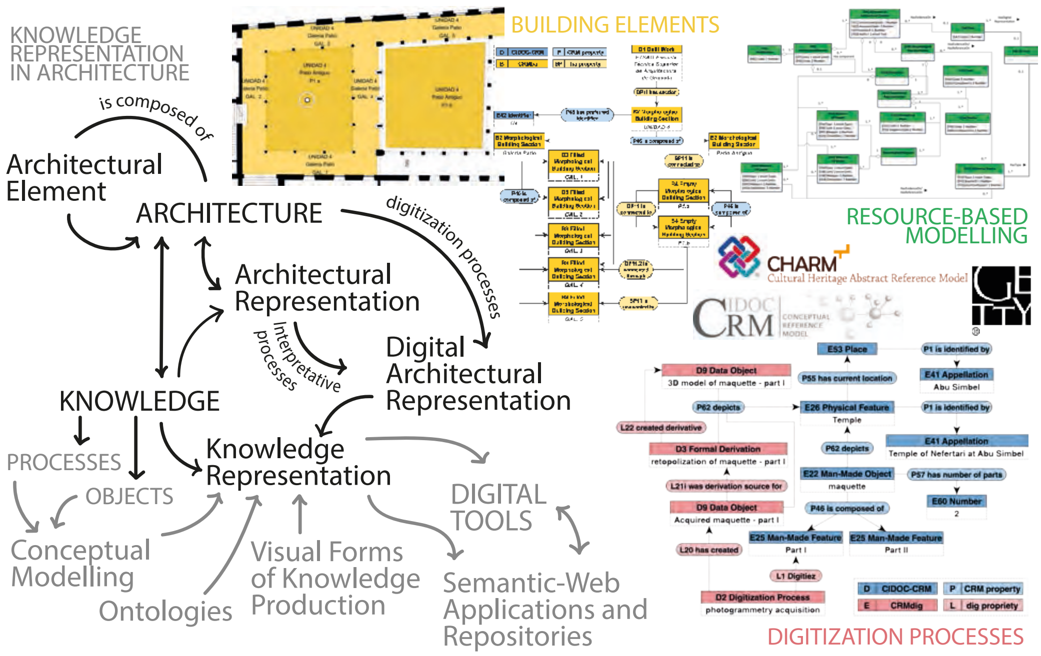


Fig. 1. Conceptual data modelling overview. On the top, conceptual modelling of H–BIM object classes using CRMba extension. On the top–right, resource–based modelling processes using CHARM model. On the bottom–right a conceptual model for the reality–based 3D modelling process using CRMdig extension.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

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

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

Conclusions

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

Notes

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

[2] The CIDOC Conceptual Reference Model (CRM). http://www.cidoc-crm.org/ (March 2021)

[3] Art & Architecture Thesaurus (AAT) – Getty Research Institute. https://www.getty.edu/research/tools/vocabularies/aat/ (March 2021)

[4] Cultural Heritage Abstract Reference Model (CHARM) – INCIPIT, CSIC. www.charminfo.org (March 2021)

[5] The Extended Matrix formal language for virtual reconstruction processes. http://osiris.itabc.cnr.it/extendedmatrix/ (March 2021)

[6] Industry Foundation Classes. https://www.buildingsmart.org/standards/bsi-standards/industry-foundation-classes/ (March 2021)

[7] An extension of CIDOC CRM to support buildings archaeology documentation. http://www.cidoc-crm.org/crmba/ (March 2021)

[8] An extension of CIDOC CRM to encode "provenance" of digitization products. http://www.cidoc-crm.org/crmdig/ (March 2021)

References

Apollonio Fabrizio I., Fallavollita Federico, Giovannini Elisabetta C., Foschi Riccardo, Corso Salvatore (2017). The Reconstruction of Drawn Architecture. In *Studies in Digital Heritage*, 1, 2017, pp. 380-395.

Apollonio Fabrizio I., Gaiani Marco, Sun Zheng (2013). Characterization of Uncertainty and Approximation in Digital Reconstruction of Ch Artifacts. In *Proceeding of Le Vie dei Mercanti XI Forum Internazionale di Studi*, pp. 860-869.

Apollonio Fabrizio I., Giovannini Elisabetta C. (2015). A Paradata Documentation Methodology for the Uncertainty Visualization in Digital Reconstruction of Ch Artifacts. In *SCIRES–IT–SCIentific RESearch and Information Technology,* 5 (1), pp. 1-24.

Bianchini Carlo, Nicastro Saverio (2018). The definition of the Level of Reliability: a contribution to the transparency of Heritage–BIM processes. In *Dn–Building Information Modeling, Data & Semantics*, 2, pp. 45-49.

Boccon–Gibod Par H., Golvin Jean–Claude (1990). Le Grand Temple d'Amon Rê a Karnak Reconstruit Par l'ordinateur. In *Les Dossiers d'Archeologie*, 153, pp. 8-19.

Borghini Stefano, Carlani Raffaele (2011). Virtual rebuilding of ancient architecture as a researching and communication tool for Cultural Heritage: aesthetic research and source management. In *DISEGNARECON*, 4 (8), pp. 71-79.

Borra Davide (2004). Sulla Verità Del Modello 3D. Un Metodo per Comunicare La Validità Dell'anastilosi Virtuale.'' In *EArcom04 Tecnologie per Comunicare l'architettura. Proceeding of the eArcom 4*, pp. 132-137.

Brunke Luca (2017). *Uncertainty in Archaeological 3D Reconstructions*. Master Thesis, University of Leiden.

Dell'Unto Nicolò, Leander Anne–Marie, Dellepiane Matteo, Callieri Marco, Ferdani Daniele, Lindgren Stefan (2013). Digital reconstruction and visualization in Archaeology: case–study drawn from the work of the Swedish Pompeii Project. In *Proceedings of the DigitalHeritage*, 1, pp. 621-628.

Demetrescu Emanuel (2015). Archaeological Stratigraphy as a Formal Language for Virtual Reconstruction. Theory and Practice. In *Journal of Archaeological Science*, 57, pp. 42-55.

Diara Filippo, Fulvio Rinaudo (2020). IFC classification for FOSS HBIM: Open Issues and a schema proposal for Cultural Heritage assets. In *Applied Sciences*, 10 (23), pp.1-23.

Frischer Bernard (2006). New directions for cultural Virtual Reality: a global strategy for archiving, serving and exhibiting 3D computers models of Cultural Heritage sites. In *Proceedings of the Virtual Retrospect 2005*, pp. 168-175.

Garagnani Simone (2013). Building Information Modeling and real world knowledge: a methodological approach to accurate semantic documentation for the Built Environment. In *Proceedings of the DigitalHeritage*, 1, pp.489-496.

Giovannini Elisabetta C. (2020). Workflow for an evidence–based Virtual Reconstruction: the marbles of the Ciborium of the Early Medieval Monte Sorbo Church. In *ISPRS Archives*, 43, pp. 1395-1402.

Giovannini Elisabetta C. (2017). VRIM Workflow: semantic H–BIM objects using parametric geometries. In Empler Tommaso (ed.). *3D MODELING &BIM. Progettazione, Design, Proposte per La Ricostruzione*. Roma: DEI Tipografia del Genio Civile, pp. 212-229.

Gonzalez–Perez Cesar, Martín–Rodilla Patricia, Parcero–Oubiña Cesar, Fábrega–Álvarez Pastor, Güimil–Fariña Alejandro (2012). Extending an abstract reference model for transdisciplinary work in Cultural Heritage. In Dodero Juan Manuel, Palomo–Duarte Manuel, Karampiperis Pythagoras (eds.). *Metadata and Semantics Research*. Berlin, Heidelberg: Springer, pp. 190-201.

De Luca Livio (2013). 3D Modeling and Semantic Enrichment in Cultural Heritage. In Dieter Fritsch (ed.). *Photogrammetric Week.* Berlin: Wichmann Verlag, pp. 323-333.

De Kramer Marleen (2020). Relict–Interpolated–Extrapolated–Speculative: an approach to degrees of Accuracy in Virtual Heritage Reconstruction. In Fotis Liarokapis, Athanasios Voulodimos, Nikolaos Doulamis, Anastasios Doulamis (eds.). *Visual Computing for Cultural Heritage*. Cham: Springer International Publishing, pp. 409-422.

Lee Y. Tina (1999). Information Modeling: from design to implementation. In *Proceedings of the Second World Manufacturing Congress*, pp. 315-321.

Maiezza Pamela (2019). As–built reliability in architectural HBIM modeling. In *ISPRS Archives*, 42, pp. 461-466.

McCurdy Leah (2010). *Visualising Architecture: The Experience of Creating Virtual Reconstructions*. Master Thesis, University of York.

Noardo Francesca (2018). Architectural Heritage Semantic 3D Documentation in Multi–Scale Standard Maps. In *Journal of Cultural Heritage*, 32, pp. 156-165.

Parisi Piergiorgio, Lo Turco Massimiliano, Giovannini Elisabetta C. (2019). The value of knowledge through H–BIM models: historic documentation with a sematic approach. In *ISPRS Archives*, 42, pp. 581-588.

Quattrini Ramona, Battini Carlo, Mammoli Raissa (2018). HBIM to VR. Semantic Awareness and Data Enrichment Interoperbility for Parametric Libraries of Historical Architecture. In *ISPRS Archives*, 42 (2), pp. 937-943

Quattrini, Ramona, Roberto Pierdicca, and Christian Morbidoni (2017). Knowledge–Based data enrichment for HBIM: exploring high–quality Models Using the Semantic–Web. In *Journal of Cultural Heritage*, 28, pp. 129-139.

Reilly Paul (1991). Towards a Virtual Archaeology. In *Proceeding of the CAA90. Computer Applications and Quantitative Methods in Archaeology 1990*, pp. 132-139.

Tedeschi Arturo (2014). *AAD, Algorithms–Aided Design: Parametric Strategies Using Grasshopper.* Brienza: Le Penseur Publisher.

Author

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

Isbn 9788835125280

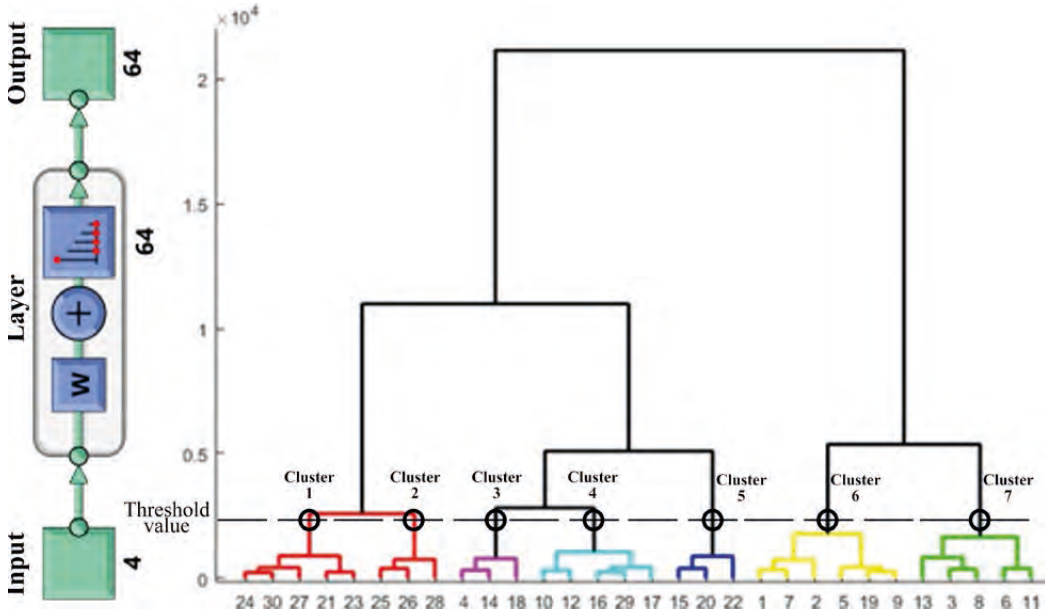
Image–Based Modelling Restitution: Pipeline for Accuracy Optimisation

Marco Limongiello
Lucas Matias Gujski

Abstract

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

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



doi.org/10.3280/oa-686.31

Introduction

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

Case Study and Data Acquisition

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

Developed Methodology and Quality Features

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

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

Analysis of Individual Accuracy Parameters

A very noisy standard portion, 50 cm wide, containing vertical walls and the inner yard, was analysed for the purpose of the study. The first parameter considered is RE. The Weibull distribution is the one best–fitting the interpolated data, therefore it was chosen to estimate the characteristic factors of the distribution. The distribution study was used to determine the threshold values, in order to remove the points with associated RE values above the estimated threshold values, more specifically those above the 99, 95, 90 percentiles.
It is possible to observe (fig. 1) how the filtering of the point cloud by analysing the RE and the statistical approach does not generate a good degree of filtering for the section under consideration; in fact, the procedure removes some spots mostly scattered, but it does not lead to great advantages in noise reduction. However, most of the isolated points were not filtered out.

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

SOM Analysis and Conclusion

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

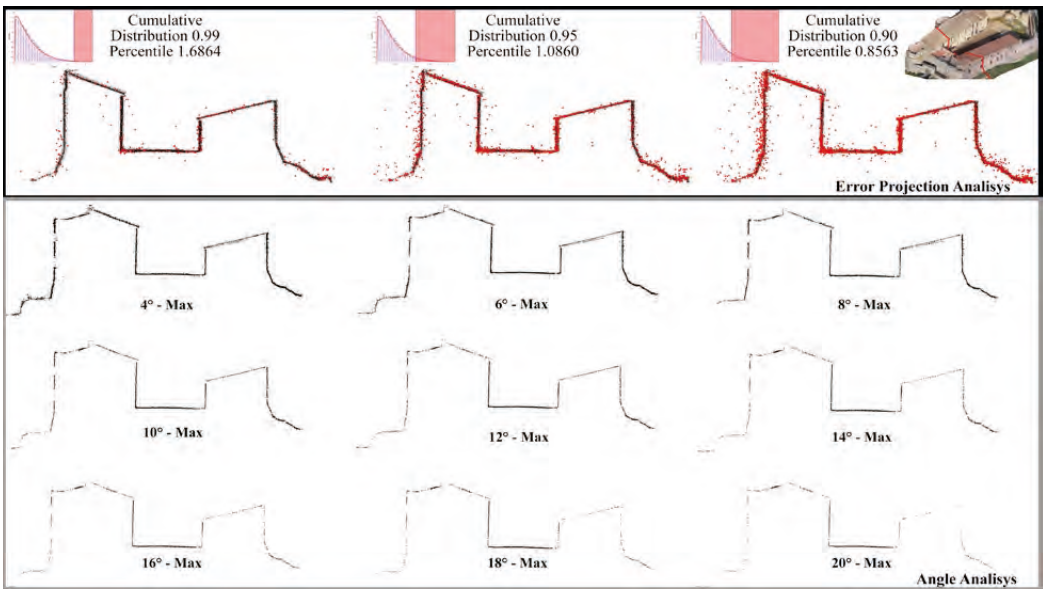


Fig. 1. Single parameter analysis of RE and intersection Angle.

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

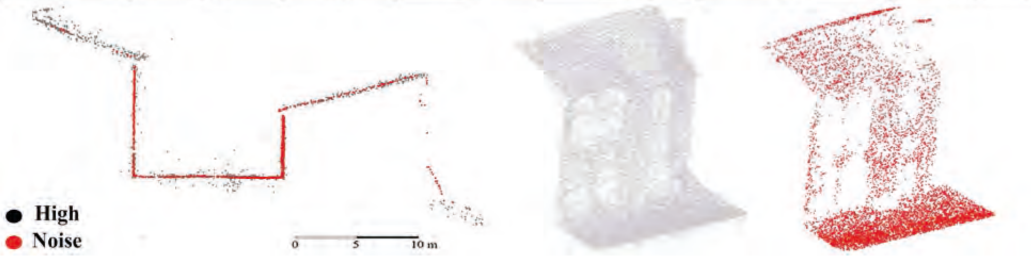


Fig. 2. Clustering and accuracy classes extracted.

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

References

Barba Salvatore, Barbarella Maurizio, Di Benedetto Alessandro, Fiani Margherita, Gujski Lucas, Limongiello Marco (2019). Accuracy Assessment of 3D Photogrammetric Models from an Unmanned Aerial Vehicle. In *Drones*, 3, pp. 1-19.

Falkingham Peter (2012). Acquisition of high resolution three–dimensional models using free, open–source, photogrammetric software. In *Palaeontologia Electronica*, 15.1, pp. 1-15.

Fernandez–Hernandez Jesus, González–Aguilera Diego, Rodríguez–Gonzálvez Pablo, Mancera–Taboada J. (2014). Image–Based Modelling from Unmanned Aerial Vehicle (UAV) Photogrammetry: An Effective, Low–Cost Tool for Archaeological Applications. In *Archaeometry*, 57, pp. 128-145.

James Mike R., Robson Stuart, d'Oleire–Oltmanns Sebastian, Niethammer Uwe (2017). Optimising UAV topographic surveys processed with structure–from–motion: Ground control quality, quantity and bundle adjustment. In *Geomorphology*, 280, pp. 51-66.

Kohonen Teuvo (2001). *Self–Organizing Maps*. 3rd edition. Berlin: Springer–Verlag.

Kraus Karl (2007). *Photogrammetry: geometry from images and laser scans*. 2nd edition. Berlin: Walter de Gruyter.

Kurasova Olga, Molyte Alma (2011). Quality of Quantization and Visualization of Vectors Obtained by Neural Gas and Self–Organizing Map. In *Informatica*, 22, pp. 115-134.

Teruggi Simone, Grilli Eleonora, Russo Michele, Fassi Francesco, Remondino Fabio (2020). A Hierarchical Machine Learning Approach for Multi–Level and Multi–Resolution 3D Point Cloud Classification. In *Remote Sensing*, 12, pp. 1-27.

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

Isbn 9788835125280

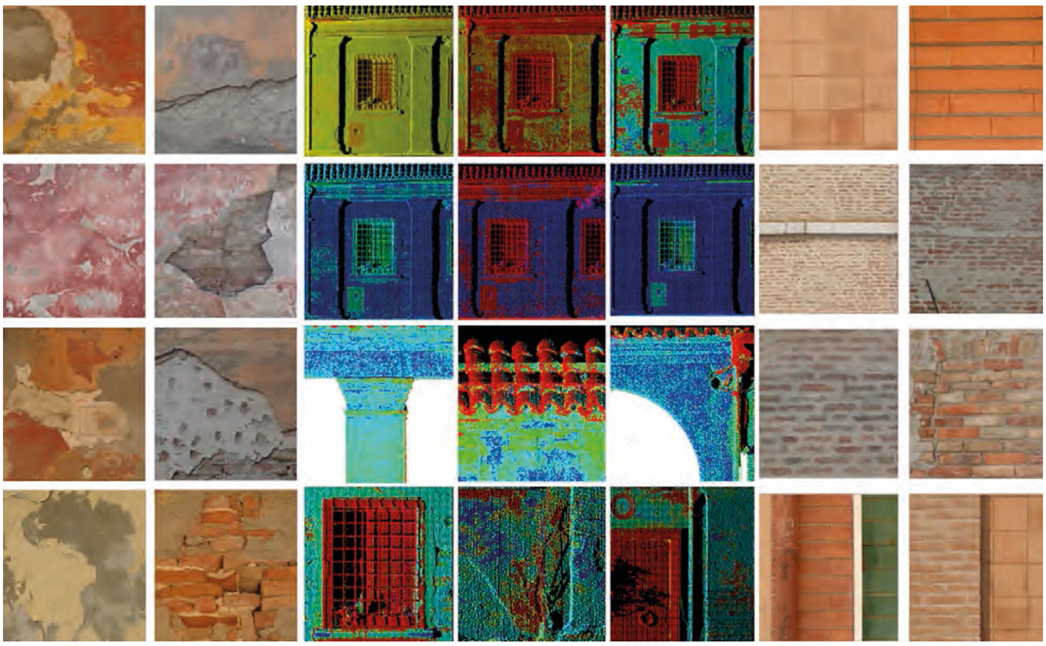
From AI to H–BIM: New Interpretative Scenarios in Data Processing

Federica Maietti
Marco Medici
Ernesto Iadanza

Abstract

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

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



doi.org/10.3280/oa-686.32

Research Scenario

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

Digital Data Processing for Heritage Conservation

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

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

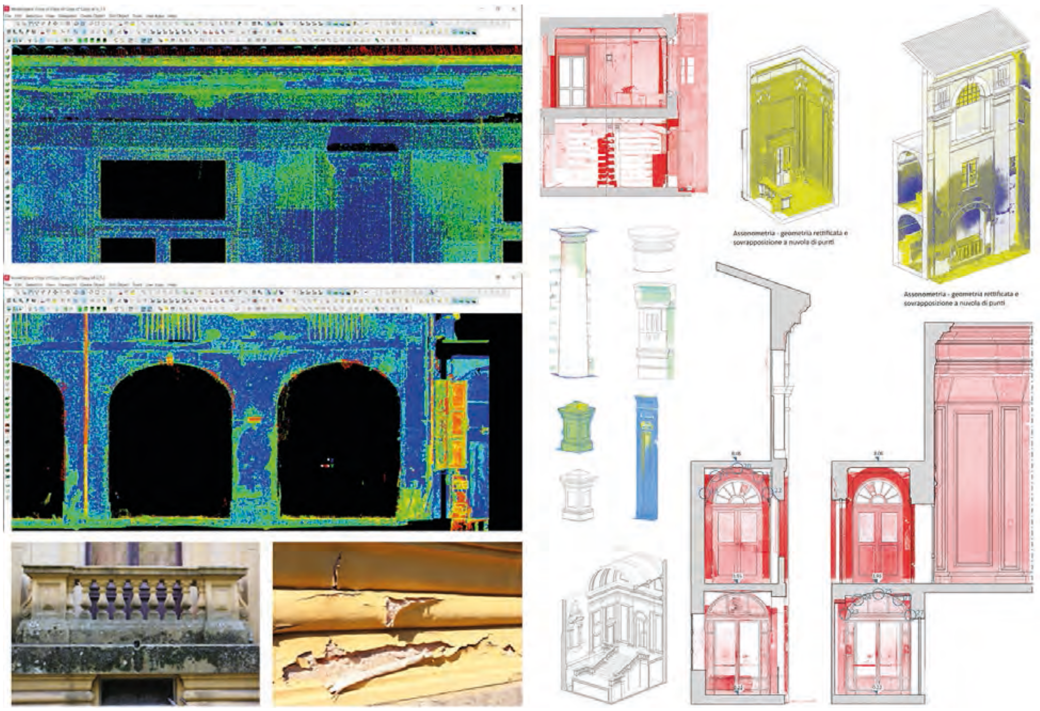


Fig. 1. Analysis of surface specifications by means of point cloud processing and data management in BIM environment.

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

From Artificial Intelligence to H–BIM

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

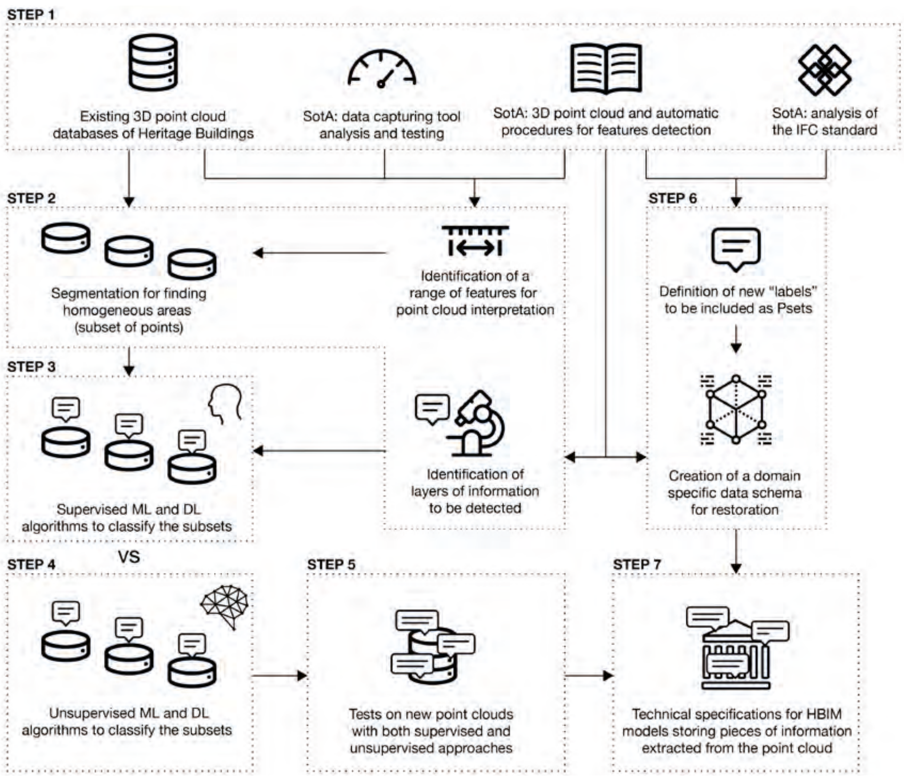


Fig. 2. Graphical schema summarizing the overall process.

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

Conclusion

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

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

Notes

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

References

Apollonio Fabrizio Ivan, Gaiani Marco, Sun Zheng (2017). A reality integrated BIM for architectural Heritage conservation. In Ippolito Alfonso (ed.). In *Handbook of research on emerging technologies for architectural and archaeological Heritage*. Hershey, PA: IGI Global, pp. 31-65.

Bienvenido–Huertas David, Nieto–Julián Juan Enrique, Moyano Juan José, Macías–Bernal Juan Manuel, Castro José (2019). Implementing Artificial Intelligence in H–BIM Using the J48 Algorithm to Manage Historic Buildings. In *International Journal of Architectural Heritage*, pp. 1148-1160.

Chiabrando Filiberto, Lo Turco Massimiliano, Rinaudo Fulvio (2017). Modeling the decay in an HBIM starting from 3D point clouds. A followed approach for cultural Heritage knowledge. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII–2/W5, pp. 605-612.

Gallozzi Arturo, Senatore Luca J., Strollo, Rodolfo M. (2019). An overview on Robotic Applications for Cultural Heritage and Built Cultural Heritage. In *SCIRES–IT–SCIentific RESearch and Information Technology*, 9 (2), pp. 47-56.

Grilli Eleonora, Menna, Fabio, Remondino Fabio (2017). A review of point clouds segmentation and classification algorithms. In T*he International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII–2/W3, pp. 339-344.

Grilli Eleonora, Özdemir Emre, Remondino Fabio (2019). Application of Machine and Deep Learning Strategies for the Classification of Heritage Point Clouds. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII–4/W18, pp. 447-454.

Janković Radmila (2020). Machine Learning Models for Cultural Heritage Image Classification: Comparison Based on Attribute Selection. In *Information*, 11 (1), 12, pp. 1-13.

López J. Facundo, Lerones Pedro M., Llamas José, Gómez–García–Bermejo Jaime, Zalama Eduardo (2018). A review of Heritage building information modeling (H–BIM). In *Multimodal Technologies and Interaction*, 2 (2), 21, pp. 1-29.

Malinverni Eva S., Pierdicca Roberto, Paolanti Marina, Martini Massimo, Morbidoni Christian, Matrone Francesca, Lingua Andrea (2019). Deep Learning for Semantic Segmentation of 3D Point Cloud. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII–2/W15, pp. 735-742.

Murtiyoso Arnadi, Grussenmeyer Pierre (2019). Automatic Heritage Building Point Cloud Segmentation and Classification Using Geometrical Rules. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII–2/W15, pp. 821-827.

Osello Anna, Acquaviva Andrea, Dalmasso Daniele, Erba David, Del Giudice Matteo, Macii Enrico, Patti Edoardo (2015). BIM and Interoperability for Cultural Heritage through ICT. In Brusaporci Stefano (ed.). *Handbook of Research on Emerging Digital Tools for Architectural Surveying, Modeling, and Representation*. Hershey, PA: IGI Global, pp. 274-291.

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

 Isbn 9788835125280

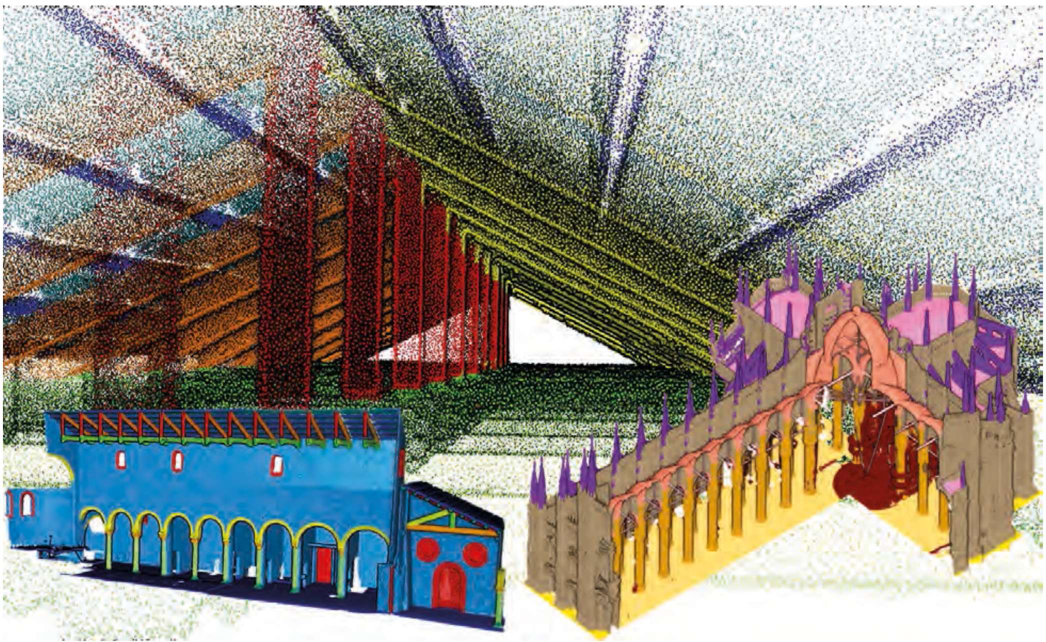
Machine Learning for Cultural Heritage Classification

Michele Russo
Eleonora Grilli
Fabio Remondino
Simone Teruggi
Francesco Fassi

Abstract

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

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



doi.org/10.3280/oa-686.33

Introduction

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

State of the Art

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

The Case Studies and Classification Purposes

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

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

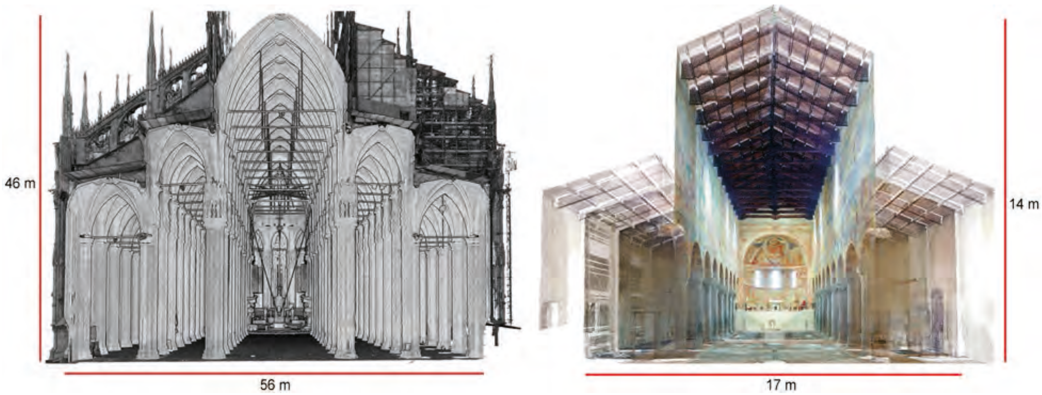


Fig. 2. A view on the point clouds of the two datasets: The Milan Cathedral (left) and the Pomposa Abbey (right).

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

The Methodological Workflow

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

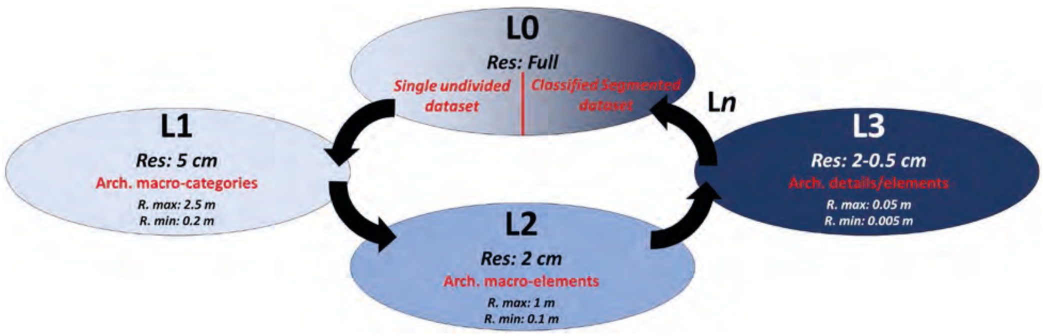


Fig. 3. Schema of the MLMR iterative process.

Experimentation and Results

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

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

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

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

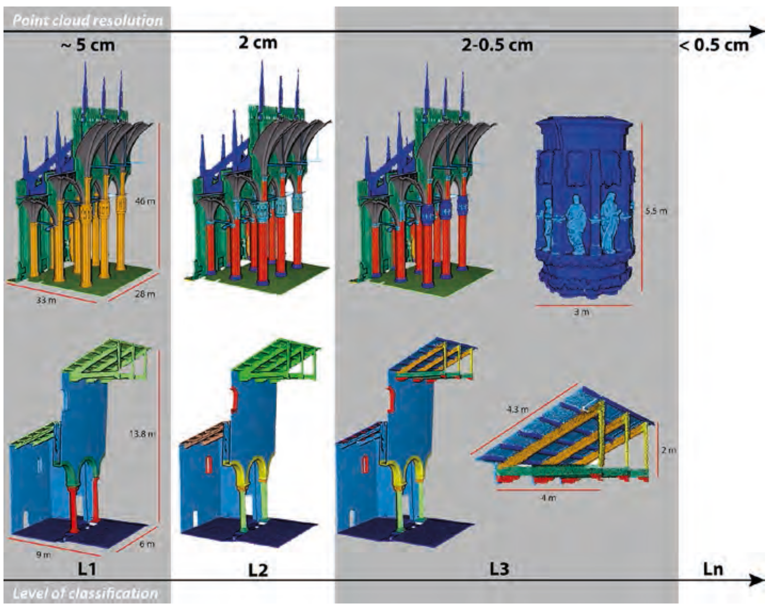


Fig. 4. The classification process of the Cathedral (top) training portion and the Basilica (bottom) according to the resolutions and levels of detail sought by the features.

Conclusions and Future Research

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

Notes

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

References

Achille Cristiana, Fassi Francesco, Mandelli Alessandro et al. (2020). From a Traditional to a Digital Site: 2008-2019. The History of Milan Cathedral Surveys. In *Digital Transformation of the Design, Construction and Management Processes of the Built Environment.* Cham: Springer, pp. 331-341.

Blomley Rosmarie, Weinmann Martin, Leitloff Jens et al. (2014). Shape distribution features for point cloud analysis–a geometric histogram approach on multiple scales. In *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, 2 (3), pp. 9-16.

Breiman Leo (2001). Random forests. In *Machine learning*, 45 (1), pp. 5-32.

Fassi Francesco, Achille Cristiana, Fregonese Luigi (2011). Surveying and modelling the main spire of Milan Cathedral using multiple data sources. In *The Photogrammetric Record*, 26 (136), pp. 462-487.

Goutte Cyril, Gaussier Eric (2005). March. A probabilistic interpretation of precision recall and F–score, with implication for evaluation. In *European conference on information retrieval.* Berlin: Springer, pp. 345-359.

Grilli Eleonora, Dininno Domenica, Marsicano Lucia et al. (2018). Supervised segmentation of 3D cultural heritage. In *3rd Digital Heritage International Congress (DigitalHERITAGE)*. USA: IEEE, pp. 1-8.

Grilli Eleonora, Remondino Fabio (2020). Machine Learning Generalisation across Different 3D Architectural Heritage. In *ISPRS International Journal of Geo–Information*, 9 (6), 379, pp. 1-19.

Matrone Francesca, Grilli Eleonora, Martini Massimo et al. (2020). Comparing Machine and Deep Learning Methods for Large 3D Heritage Semantic Segmentation. In *ISPRS International Journal of Geo–Information*, 9 (9), 535, pp. 1-22.

Pierdicca Roberto, Paolanti Marina, Matrone Fracesca et al. (2020). Point Cloud Semantic Segmentation Using a Deep Learning Framework for Cultural Heritage. In *Remote Sensing*, 12 (6), 1005, pp. 1-23.

Russo Michele, Manferdini Anna Maria (2014). Integration of image and range–based techniques for surveying complex architectures. In *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.,* 2 (5), pp. 305-312.

Teruggi Simone, Grilli Eleonora, Russo Michele (2020). A Hierarchical Machine Learning Approach for Multi–Level and Multi–Resolution 3D Point Cloud Classification. In *Remote Sensing*, 12 (16), 2598, pp. 1-27.

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

 Isbn 9788835125280

Photogrammetric Survey for a Fast Construction of Synthetic Dataset

Andrea Tomalini
Edoardo Pristeri
Letizia Bergamasco

Abstract

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

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

doi.org/10.3280/oa-686.34

Introduction

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

Case Study Definition and Data Acquisition

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

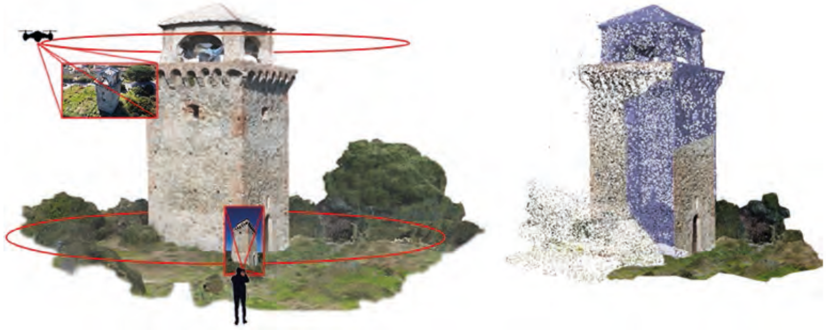


Fig. 1. Conceptual scheme of the survey and construction phases of the textured mesh model.

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

Dataset Construction Workflow

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

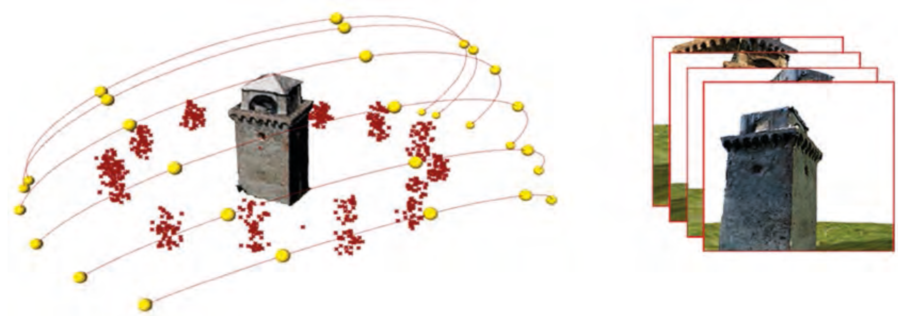


Fig. 2. Selection throughout the year of 30 different lighting conditions and relative camera positions.

Test Classification Pipeline

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

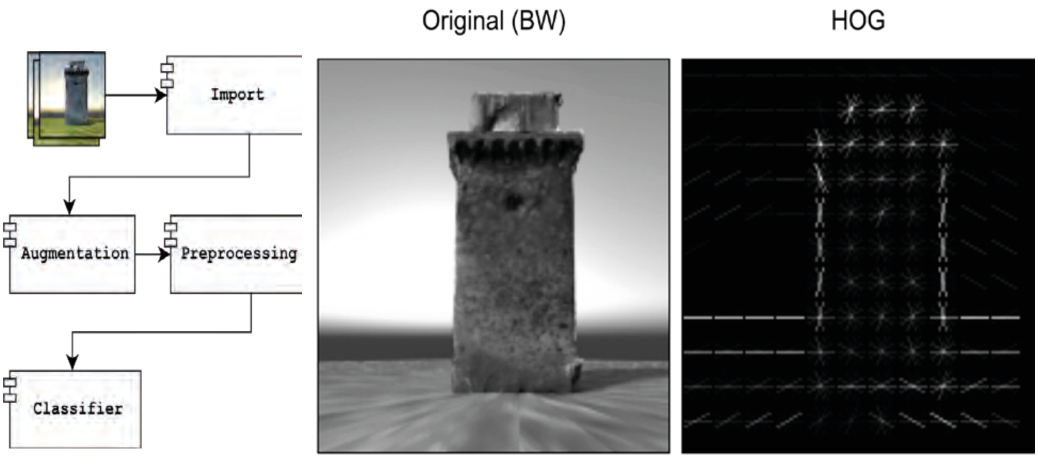


Fig. 3. From the left: Classification pipeline architecture; Two intermediate outputs of the pipeline stages.

Dataset Construction Improvements

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

Conclusions

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

References

Andrianaivo Louis N., D'Autilia Roberto, Palma, Valerio (2019). Architecture recognition by means of convolutional neural networks. In *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*, 42 (2/W15), pp. 77-84.

Barsanti Sara Gonizzi, Malatesta Saverio Giulio, Lella Francesco, Fanini Bruno, Sala Francesco, Dodero Eloisa, Petacco Laura (2018). The Winckelmann300 project: dissemination of culture with virtual reality at the Capitoline Museum in Rome. In *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*, 42 (2), pp.371-378.

Bottou Leon (2010). Stochastic Gradient Descent. https://leon.bottou.org/projects/sgd (16th February 2021).

Calantropio Alessio, Chiabrando Filiberto, Spanò Antonia (2018). Impiego di tecniche di fotogrammetria digitale speditiva a supporto delle opere provvisionali negli interventi tecnici in emergenza sismica. In *Bollettino SIFET*, 3, pp. 22-31.

Cardenal Escarcena E.J., Mata Emilio, Castro P., Delgado Jorge, Hernandez M. A., Perez Jose Luis, Ramos M., Torres Manuel (2004). Evaluation of a digital non metric camera (Canon D30) for the photogrammetric recording of historical buildings. In *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 35 (B5), pp. 564-569.

Liu Li, Ouyang Wanli, Wang Xiaogang, Fieguth Paul, Chen Jie, Liu Xinwang, & Pietikäinen Matti (2020). Deep learning for generic object detection: A survey. In *International journal of computer vision*, 128 (2), pp. 261-318.

Lo Turco Massimiliano, Piumatti Paolo, Calvano Michele, Giovannini Elisabetta Caterina, Mafrici Noemi, Tomalini Andrea, Fanini Bruno (2019). Interactive Digital Environments for Cultural Heritage and Museums. Building a digital ecosystem to display hidden collections. In *Disegnarecon*, 12 (23), pp. 7.1-7.11.

Luhmann Thomas (2010). Close range photogrammetry for industrial applications. In *ISPRS journal of photogrammetry and remote sensing*, 65 (6), pp. 558-569.

Nocerino Erica, Menna Fabio, Remondino Fabio, Saleri Renato (2013). Accuracy and block deformation analysis in automatic UAV and terrestrial photogrammetry–Lesson learnt. In *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2 (5–W1), pp. 203-208.

Norouzzadeh Mohammad Sadegh, Nguyen Anh, Kosmala Margaret, Swanson Alexandra, Palmer Meredith S., Packer Craig, Clune Jeff (2018). Automatically identifying, counting, and describing wild animals in camera–trap images with deep learning. In *Proceedings of the National Academy of Sciences*, 115 (25), pp. 5716-5725.

Spallone Roberta, Palma Valerio (2020). Intelligenza artificiale e realtà aumentata per la condivisione del patrimonio culturale. In *Bollettino SIFET*, 2, pp. 1-8.

Vayanou Maria, Karvounis Manos, Katifori Akrivi, Kyriakidi Marialena, Roussou Maria, & Ioannidis Yoannidis (2014). The CHESS Project: Adaptive Personalized Storytelling Experiences in Museums. In *UMAP Workshops*, p. 232-235.

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

 Isbn 9788835125280