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

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Abstract

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

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

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Introduction

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

The Case Study: Brief Historical Description

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

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

Photogrammetry Survey and Post-processing

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

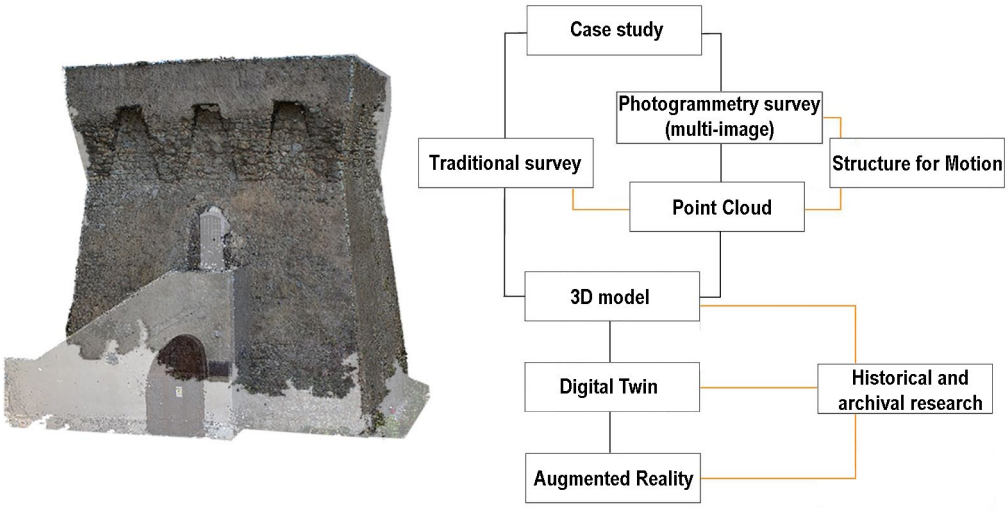

Fig. 1. Overlay between the pre and post restoration photogrammetric model and general workflow.

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

Reconstructive Hypothesis

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

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

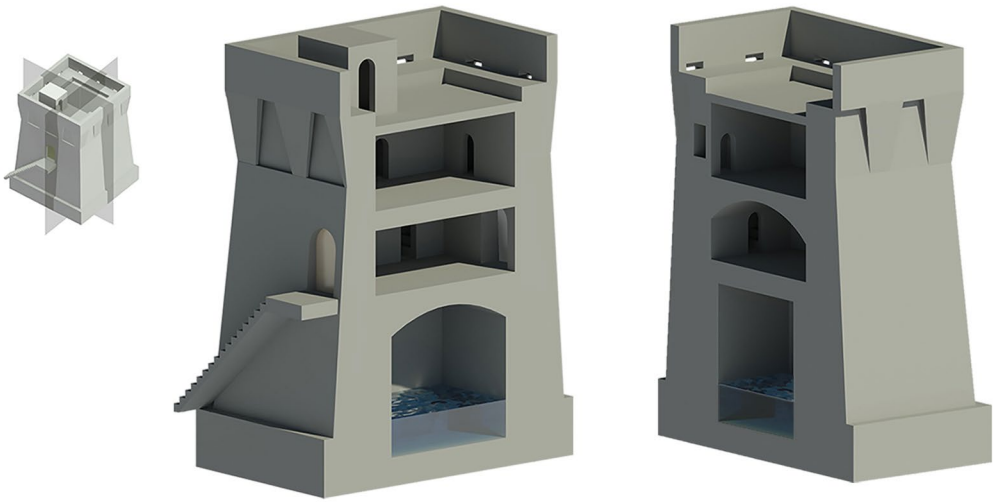

Fig. 3. Representative BIM model of the initial Torre dell'Isola configuration hypothesis.

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

Augmented Reality

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

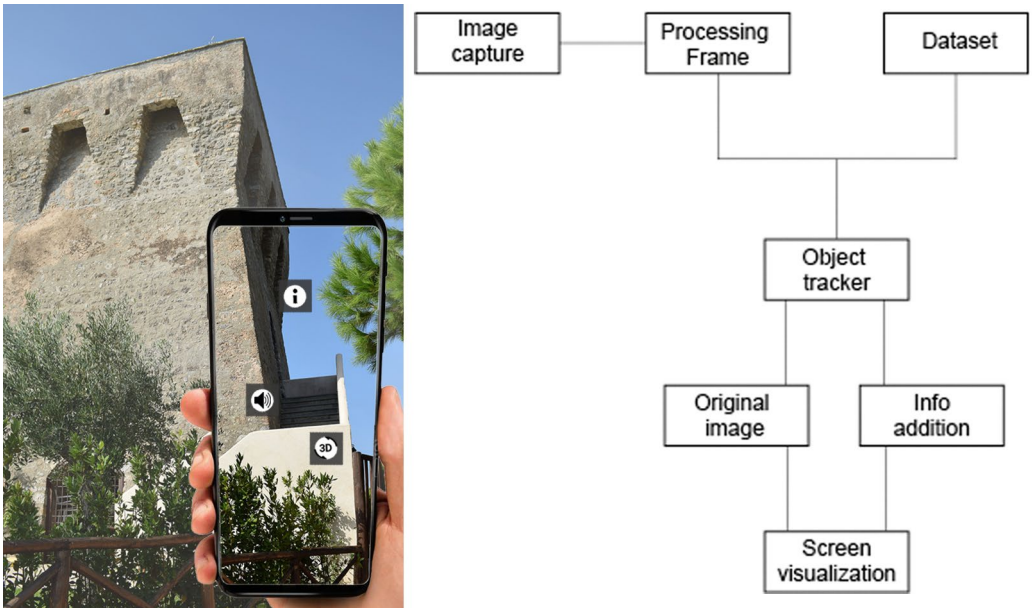

Fig. 4. Augmented reality application and workflow.

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

Conclusion

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

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

References

Antinozzi Sara, Ronchi Diego, Fiorillo Fausta, Barba Salvatore (2021). Dino: Configuration for a Micro-Photogrammetric Survey – Applying Dino-Lite microscope for the digitalization of a cuneiform tablet. In Stojakovic Vesna, Tepavcevic Bojan (eds.). *Towards a new, configurable architecture. Proceedings of the 39th eCAADe Conference*, 2, 2021, pp. 211-222.

Aversano Vincenzo (1976). Le torri costiere del Cilento. In *Confronto Rivista bimestrale di politica sociale e di attualità culturale, 1* (3), 1976, pp. 395-403.

Cannella Mirco (2021). Hulot's Selinunte: Digital analysis and virtual reconstruction. In *SCIentific RESearch and Information Technology,* 11 (2), 2021, pp. 113-124.

Colace Francesco, Elia Cristina, Guida Caterina Gabriella, Lorusso Angelo, Marongiu Francesco, Santaniello Domenico (2021). An IoT-based Framework to Protect Cultural Heritage Buildings. In *IEEE International Conference on Smart Computing, SMARTCOMP 2021*, pp. 377-382.

Gabellone Francesco (2020). A digital twin for distant visit of inaccessible contexts. In *IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage*. Trento, Italy, pp. 232-237.

Guida Caterina Gabriella, di Filippo Andrea, D'Agostino Pierpaolo (2021). Scan-To-Bim Procedure for an Old Industrial Plant. In Karabegović Isak (ed.). *New Technologies, Development and Application IV. NT 2021. Lecture Notes in Networks and Systems*, 233, 2021. Cham: Springer, pp. 1019-1026.

Kassahun Bekele Mafkereseb, Pierdicca Roberto, Frontoni Emanuele, Malinverni Eva Savina, and Gain James (2018). *A Survey of Augmented, Virtual, and Mixed Reality for Cultural Heritage. In Journal on Computing and Cultural Heritage*, 11 (2), 2018, pp. 7:1-7:36.

Mekni Mehdi; Lemieux André (2014). Augmented reality: Applications, challenges and future trends. In Azami Zaharim (ed.) *Proceedings of the 13th International Conference on Applied Computational Science*. Kuala Lampur: WSEAS, pp. 205-214.

Merchán María José, Merchán Pilar; Pérez Emiliano. Good Practices in the Use of Augmented Reality for the Dissemination of Architectural Heritage of Rural. In *Applied Sciences*, 11 (5), 2021, 2055, pp. 1-20.

Pignatelli Spinazzola Giuseppe (2007). Programmi difensivi vicereali e architetture fortificate sulla costa amalfitana. In Gambardella Alfonso, Jacazzi Danila (eds.). *Architettura del classicismo tra Quattrocento e Cinquecento. Campania ricerche*. Roma: Gangemi, pp. 294-311.

Russo Flavio (2001). *Le torri anticorsare vicereali*. Napoli: Istituto Italiano dei Castelli Sezione Campania.

Russo Flavio (2009). *Le Torri Costiere del Regno di Napoli. La frontiera marittima e le incursioni corsare tra il XVI e il XIX secolo*. Napoli: Edizioni Scientifiche e Artistiche.

Russo Michele (2021). AR in the Architecture Domain: State of the Art. In *Applied Sciences*, 11 (15), 2021, 6800, pp. 1-38.

Santoro Lorenzo (2012). *Le torri costiere della provincia di Salerno*. Napoli: Paparo edizioni.

Talenti Simona, Morena Sara (2016). Da Positano a Sapri: la rete di "sguardi" del sistema difensivo costiero. In Verdiani Giorgio (ed.). *Defensive Architecture of the Mediterranean XV to XVIII Centuries. International Conference on Modern Age fortifications of the Mediterranean coast, FORTMED*. Firenze: Didapress, pp. 169-176.

Vassalluzzo Mario (1975). *Castelli torri e borghi della Costa Cilentana*. Castel San Giorgio, Salerno: Edizioni ECON.

Vitali Marco, Bertola Giulia, Natta Fabrizio, Ronco Francesca (2020). AI+AR: Cultural Heritage, Museum Institutions, Plastic Models and Prototyping. A State of Art. In Giordano Andrea, Russo Michele, Spallone Roberta (eds.). *Representation Challenges. Augmented Reality and Artificial Intelligence in Cultural Heritage and Innovative Design Domain*. Milano: FrancoAngeli, pp. 59-63.

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