Sandro Parrinello
Anna Dell'Amico

Salvatore Barba
Andrea di Filippo

editors

D-SITE

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Editors
Sandro Parrinello, Salvatore Barba, Anna Dell'Amico, Andrea di Filippo

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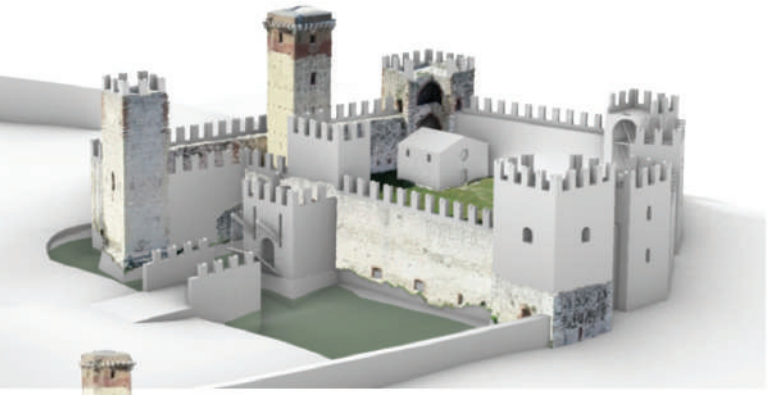

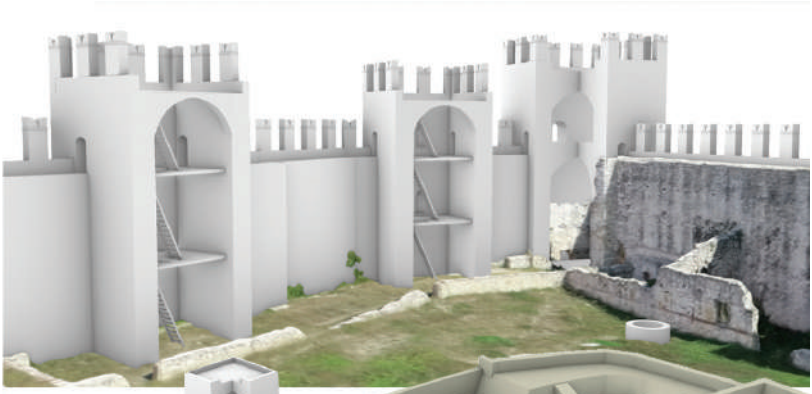

Alberto Pettineo

DICAr, Department of Civil Engineering and Architecture,
University of Pavia,
Pavia, Italy

alberto.pettineo01@universitadipavia.it

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Videogrammetry, 3D virtual reconstruction, Cultural Heritage, Montorio, Scaliger castles.

ABSTRACT

The submitted paper deals in a research that concerns documentation systems for the Scaliger fortifications in the Verona area by using a case study: the Montorio Castle. The research aims to analyze the possibilities offered by drones for the creation of 3D models using frames exported from video footage. This activity creates a groundwork for the philological reconstruction of the military structures through its main construction phases. Accordingly, a possible development is to begin a process to enhance and preserve the historical knowledge of these fortifications through studying and describing them.

Videogrammetry for the virtual philological reconstruction of the Scaliger fortifications in the territory of Verona. The case study of Montorio Castle

1. Introduction

Fortification is an element that identifies the territory; its presence has always shaped and characterized the development of the surrounding space (Creighton, 2002). This connection between the fortress and the territory is clearly noticeable in Veneto. In this area, mainly in Verona province, there are many castles built between the thirteenth and fourteenth centuries during the Scaliger domination period. Part of those castles have reached the present day in an excellent state of conservation, such as Soave and Sirmione, others have come to us as ruins or partially modified, in such a way that the original conformation and its relation with the territory is no more easily understandable. For this reason, representing military architecture is a complicated process: it concerns understanding the territory that affects the characterization of the design of a particular defensive structure, but also documenting how much of these structures has been preserved. (Parrinello 2019). In order to do that, the research presented in this paper aims to analyze the possibilities offered by drones for the creation of 3D models using frames exported from video footage. The application of this method can help to start a process in order to enhance and preserve the historical knowledge of these fortifications. Various documentation activities on Scaliger castles have been promoted as a part of the collaboration agreement between the Department of Civil Engineering and Architecture of the University of Pavia and the Unesco Relations Office of Verona Municipality for the documentation of historical city walls. This actions aimed at the protection and enhancement of the fortified heritage in order to promote the strong cultural identity of the territory. Especially, the Montorio castle proved to be an excellent case study for test out of different steps of the research: from the documentation to the development of 3D models describing the different transformation phases the castle has gone through.

2. The history of the Montorio castle

Over the centuries the castle became strategically very important due to its privileged position in the surrounding area, and because of that has gone through several transformations. The territory on which the castle of Montorio stands is an area inhabited since ancient times. Thanks to numerous archaeological excavations begun in the 80s till nowadays, traces have emerged dating back to the Neolithic period (4000- 2200 BC) or the Copper Age (2400-1800 BC). The traces of the first castelliere date back to the VIII BC, when the ancient Venetians settled in the area where the Reti would have settle about a century later. Later on, was also proven the presence of the Cenomanian Gauls and the Romans (Alloro and Pasa, 2003). Anyway, the construction of the fortress on top of the ancient castelliere remains dates back to the beginning of the 10th century as a response to the frequent raids of the Hungarian populations (Simeoni, 1953). The current castle ruins date back no earlier than 1117, the year in which an earthquake seriously damaged the city of Verona. This event probably also has affected the Montorio castle. Infact, from the stratigraphic analysis on the walls it emerges that the current castle is dated after 1117 so the earthquake must have destroyed the old fortification on Montorio hill and due to that it was completely rebuilt after that event[1].

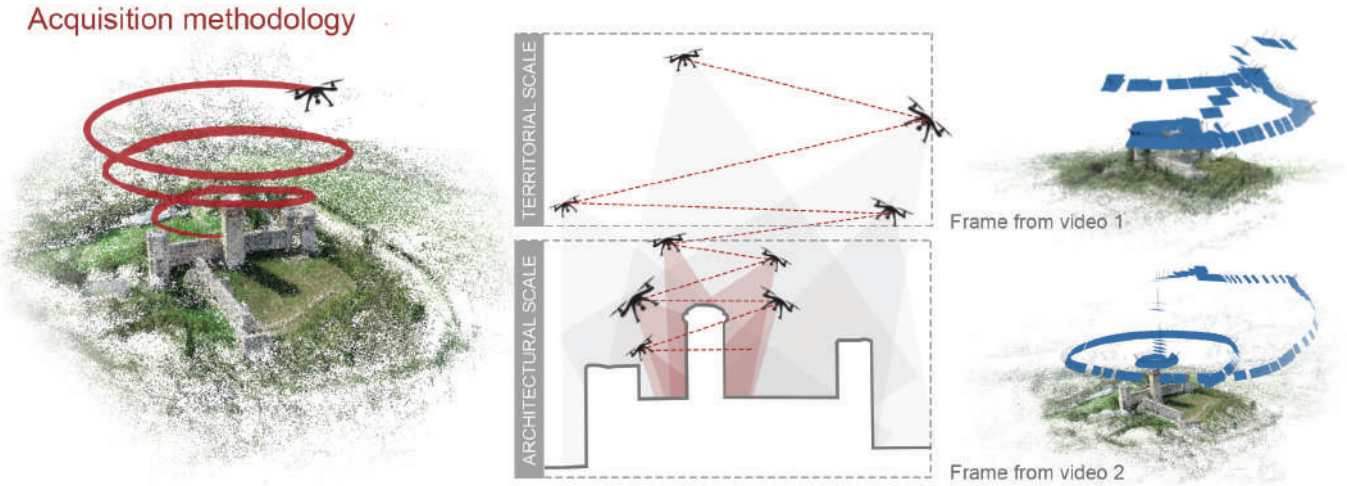

Figure 1. Flight-paths for drone's video registration and results from the frame allignment of the two video used. It is also noteworthy the camera position for each frame exported in the video sequence.

During the years of Federico Barbarossa's empire (1155-1190), the castle played a strategic role controlling a vast territory near the city of Verona and important communication routes. For this reason, Montorio has become the point of contention between the most powerful Veronese families, such as the Sambonifacio and the Crescenzi. When in 1262, Mastino della Scala was elected "Perpetual captain of the people of Verona", the castle passed under the Scaliger dominion. In 1313 when the castle was set on fire by the Paduans (in war with Cangrande Della Scala) it has been subsequently restructured. With the fall of the Della Scala family, the castle passed into the hands of the Visconti and later of the Venetians. In this period, the castle slowly loses importance with long and dusty periods of neglect[2] until the advent of the Austro-Hungarian Empire. Indeed, after defeating the Napoleonic army in 1814, the Austrians understood the strategic importance of the area of the Preafitta ridge and decided to convert the castle into a large defensive battery. During this period the castle underwent significant interventions, including the demolition of some towers and the removal of the crenelated wall. The documentation of these transformations have come to us thanks to several historical reports that described the castle[3].

3. UAV SYSTEM: SURVEY METHODOLOGIES FOR THE DEFENSIVE SYSTEM AND DATA PROCESSING

The digitization of the fortified heritage through the creation of 3D databases is a process that requires preliminary assessments of the methodologies and an accurate selection of tools to best represent the objects of study. Furthermore, is critical to evaluate the timing, the morphology and the territorial extension of the data, especially the purposes that must be achieved (Parrinello et al. 2020). The trial on the castle of Montorio through video frame processing techniques taken with UAV equipment, was born with the idea of acquiring a great number of data covering large territorial portions for the digital representation of the fortified heritage through 3D models. Images captured for photogrammetric modeling can be taken with either a still camera or a moving camera. In this case study it was decided to use video sequences[4]. During the survey phase, two high-resolution videos (about four minutes each) were made with a DJI Phantom 4 Pro UAV[5]. The video shootings were carried out working on two different scales: a punctual one aimed at the most valuable elements of the castle such as the dungeon; and a territorial one that involved the castle, the

Figure 2. Frames sequence and quality.

bastia and a part of the surrounding space.
Unlike some case studies carried out on fortified elements[6] realized using SfM techniques through static images, where generally for each punctual element is planned radial flight-path while for the territorial elements a grid, in this case study both videos were made by performing a manual flight following a radial path with heights variations for both detail scales, architectural and territorial ones (Figure 1). During the post-production phase, the videos were processed by exporting each frame (VLC Media Player) in sequence, creating two distinct photographic datasets. As in the case of traditional close-range photogrammetry, processed from cameras, the frames were extrapolated sequentially trying to have sufficient overlap between them (Figure 2). The exported frame format is the same of the shot video, 4k quality, 3810x2160 pixel, with 96ppi resolution. For the first video, lasted 4 minutes and 44 seconds has been created a 182 frame dataset, while the second video, 4 minutes and 12 seconds, the dataset is 172 frame. For each video, a dataset containing the generated frames was created and imported into an image processing software (Agisoft Metashape), generating a sparse cloud (for each dataset) representing the result of the alignment

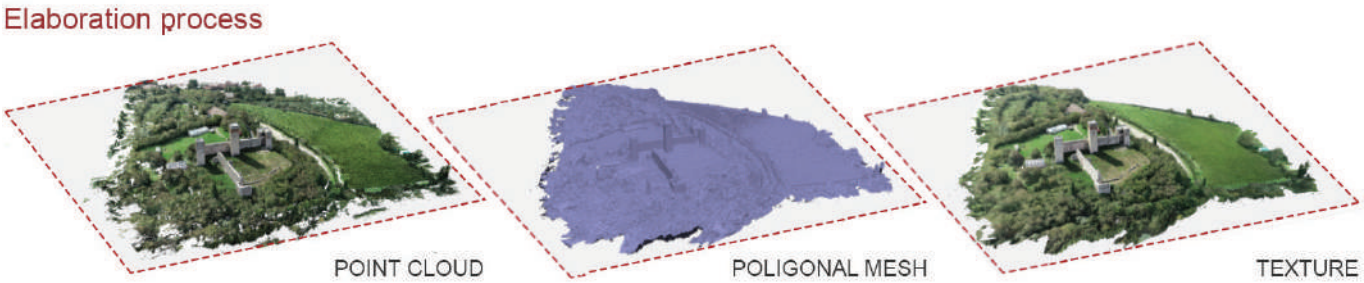

Figure 3. Following steps of photogrammetric elaboration (after alignment) and final texturized model.

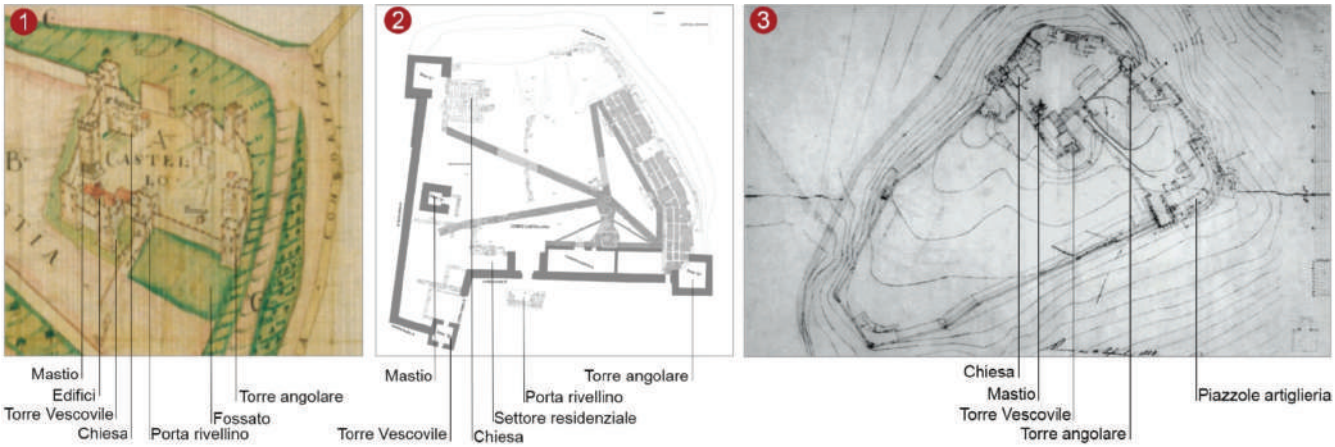

Figure 4. Representations of the castle: 1- Drawing made by Iseppo Cuman in 1663 (details); 2- Plan of archaeological excavations carried out in 2013; 3- Austrian survey dating back to 1859.

of the cameras. For the first dataset the generated sparse cloud contains 499,523 points, while the second dataset a sparse cloud of 477,729 points. Then, the two sparse clouds were aligned (automatic alignment by points) and joined, generating a unified cloud. The dense cloud was first processed and then elaborated into a polygonal mesh (19,821,151 polygons). Following this step the texture was generated, to emphasize the material characteristics (Fig.3). In the last phase, the model was scaled on the reference of the existing plan[7]. The final model has enough resolution for visualization purpose and virtual fruition.

4. Study of historical documentation for a process of philological reconstruction

The following philological reconstruction, carried out by consulting archival records provided by the Municipality of Verona, was structured based on the two main historical phases that changed the castle image. The two historical periods taken into consideration are the Scaliger period and the phase of Habsburg domination. During this later one, the castle has suffered several changes whit the aim to reconvert it into a defensive battery. In order to digitally reconstruct the elements that no longer exist, an important amount of broad spectrum information was used. In the development of the Scaliger phase, the historical drawings were essentials; among them was of the utmost importance the one created in 1663 by Iseppo di Cuman[8]. In his representation, it is possible to identify the presence of a moat in the south-eastern portion of the wall with a drawbridge that led to the entrance of the castle. Moreover, in the forepart of the currently existing portal there was a rivellino gate system of which it is still possible to see the foundations recovered following numerous archaeological excavations (Figure 4). Likewise for the portion of the north-eastern wall, no longer existing (as it was demolished and replaced by a series of embankments used as defensive spots during the nineteenth century), the archaeological evidences and the map of Cuman have allowed to reconstruct the perimeter layout of this portion of the boundary. On the city walls there were also towers that articulate the ring path. To find out in what number and in what position they were, numerous historical sources[9] were used, integrated with the representation of Cuman. Similar structures from the castles of Soave and Sirmione were taken as a model for the architectural characteristics of the towers (Calisi, Cianci 2018). For the philological reconstruction of the Habsburg period, various survey made on the castle by the Austrian Military Engineers were used, in particular one made

Figure 5. Modeling phases of the Scaliger reconstruction.

in 1859 [10] and one dated 1860 in which the detailed plan of the castle and the wall of the bastia is combined with a series of sections of the newly constructed defensive works. To support the cartographic information, photographs and historical memories were used too.

5. Digital reconstruction: operational process and results

Once generated the textured model, it was imported for the digital reconstruction of the castle within the mesh management software, Rhinoceros. For the reconstruction of the castle, in the texturized model, only the portion of the wall that currently exists was maintained as the modifications that took place over the centuries have also affected the conformation of the land in a conspicuous manner. In fact, in the reconstruction of the Scaliger period, the riverbed of the ditch was modeled, while in the Austrian reconstruction all the shooting ranges within the walls and in the north-eastern portion of the fortress were rebuilt. In the reconstruction of the medieval period, following the modeling of the terrain, the volumes of the towers and the missing perimeter of the wall were extruded. In the last phase, the elements inside the parade ground (such as the church and the houses, found in the 1664 drawing) were modeled[11] (Figure 5). The changes in the conformation of the fortification that occurred during the Asbrugic period were recreated in the second reconstruction, thanks to the inclusion of the 1859 relief within the software. After being scaled on the textured model, it was used as a reference for the extrusion of volumes. The result is two models that frame the historical moments of the fortress and in which it is possible to observe and analyze the changes that have occurred over the centuries.

To highlight the existing castle from the historical reconstruction, the model was treated and highlighted with chromatic differences to distinguish the existing (textured portion) and the reconstruction operation (Figure 6).

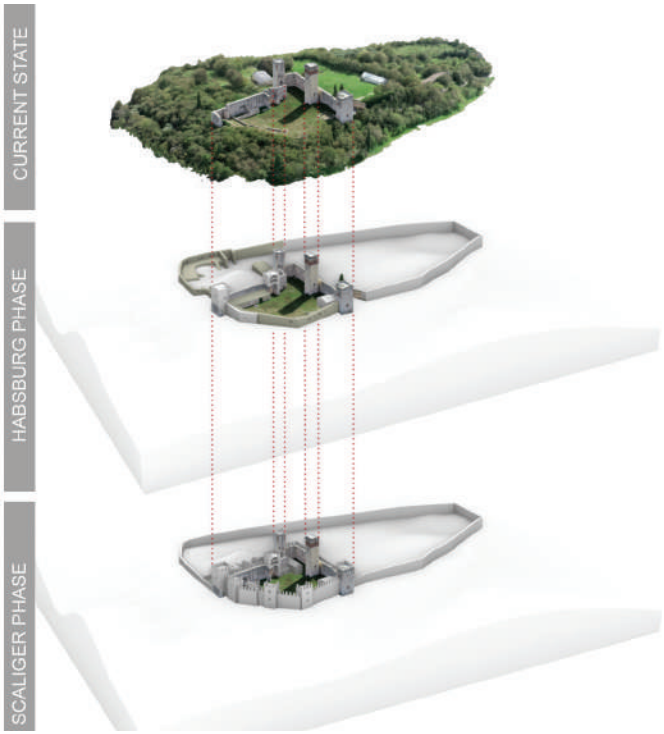

Figure 6. Reconstruction phases, results.

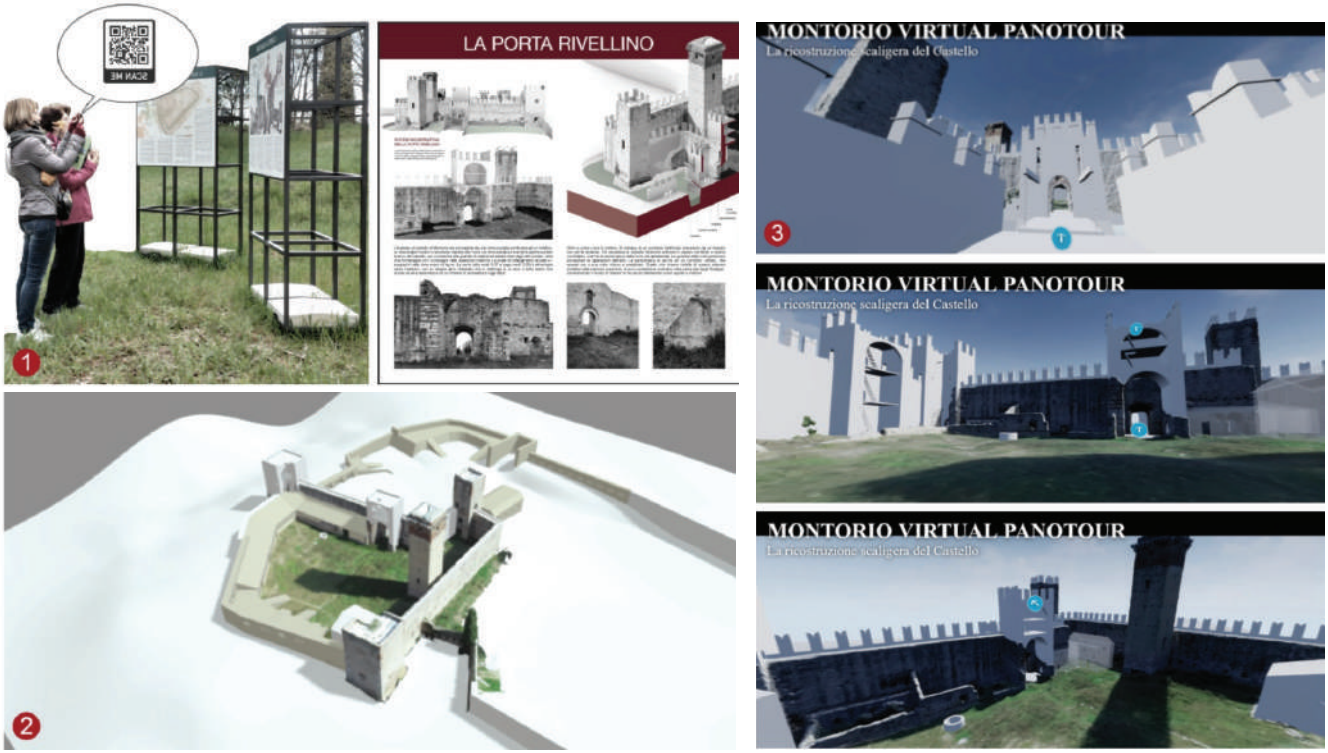

Figure 7. Fruition opportunities: 1 – Graphic reconstructions for exhibitions; 2 – Models available online; 3- Creation of virtual tours (panotour).

6. Conclusions

The 3D model developed can serve many purposes: its use can help to understand and study the Scaliger defensive systems and to comprehend the changes the castle has undergone over time. In a museological perspective, the potential of a 3D reconstruction can be exploited by the creation of virtual and augmented reality systems.

Within the framework of exposition, it can be viewed through digital devices scanning a QR Code printed on the exhibition panels (Figure 7). Otherwise, through the potential of 3D printing, it is possible to create a physical model to give the possibility of use to all age groups and people with disabilities. In this way, the municipality of Verona promoted an exhibition inside the Montorio Castle aiming to explain the cultural relations and historical events that have gone through these defensive systems. 3D models of the philological reconstructions were used in various ways: for the creation of 2D drawings explaining the architectural elements, for virtual tours and online models that can be used by scanning the QR code.

In conclusion the application of this type of methodology is successful for the creation of 3D models suitable for online use. Furthermore, the rapidity of acquisition allows it to be extended to a territorial study of the castles in order to better understand the role, as a defensive spots, that they have played over the centuries, especially during Della Scala government. Clearly an increasing interest in studying the castles from a territorial scale can lead to a broader understanding of it. The enhancement of the landscape and its stone architectures allow the creation of cultural paths that can favour tourism and the rediscovery of these architectures often forgotten by history.

Notes

1 L. Alloro, M. Pasa, 2003, p.43.

2 Ivi, p.58.

3 One of this description is provided by Carlo Belviglieri in Grande illustrazione del Lombardo-Veneto, 1859: "…bello e pittoresco fino a questi ultimi giorni né quali venne brutalmente mutilato dagli austriaci".

4 For more information about projects that used documentation methodology with video frames see: Croce V., Martínez-Espejo Zaragoza I. (2018).

5 Drone's characteristics: video resolution 4K/60fps, camera sensor: CMOS 1", pixel: 20M, focus: 8,8 mm/24 mm (format 35 mm) f/2.8 -f/11 autofocus. The video shooting quality is 4k, frame width 3810, frame height 2160, 29.97 fps.

6 To compare different SfM methodology applied to fortification documentation, see: Picchio F., Pettineo A. (2019); De Feo M. (2020); Liuzzo M. et al (2020); Versaci A. et al (2021).

7 The plan, attached in the archeological report and drawn after the excavation of 2013 realized by Thompson Simon - scavi e rilevamenti archeologici and kindly shared by the municipality Verona.

8 Drawing realized by Iseppo Cuman in 1663, taken from Alloro L., Pasa M. (2003). Il castello di Montorio. Analisi storica, socio-economica e architettonica, p. 69.

9 Among the historical sources need to be mentioned the one written by G. Orti Manara in 1824: "Esso… ha sette torri nel su recinto, ed una nel mezzo"; and the one date back to 1854 included in the poem Invito a Montorio: "L'attuale castello di Montorio [è] cinto da sette torri con una nel mezzo".

10 Habsburg survey date back to 1859, taken from Alloro L., Pasa M. (2003). Il castello di Montorio. Analisi storica, socio-economica e architettonica, p.79.

11 Luisi R., (1996), pp.42-45, the author describes the residential aspect inside the castle. Generally, the castle enclosure contained houses, stables, warehouses and vegetable gardens. In the case of Montorio, the representation of Cuman is confirmed by traces of buildings that emerged during the archaeological excavations.

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