Long Paper

Archaeological Documentation During a Securing and Restoration Project: An Example of a Successful Approach

The Case of the Castle of Larciano (Pistoia – Italy)

Lapo SOMIGLI, SAGAS Department – University of Florence, Laboratori Archeologici San Gallo (academic spinoff), Italy
Chiara MARCOTULLI, Laboratori Archeologici San Gallo (academic spinoff), Italy
Francesca CHELI, SAGAS Department – University of Florence, Laboratori Archeologici San Gallo (academic spinoff), Italy

Abstract: This paper presents the photogrammetric survey of a medieval castle and the challenges we faced in obtaining complete and accurate documentation. It focuses on the specific workflows that the different documented structures require. The objectives of the archaeological survey were to document the buildings before restoration work and to give the 3D models to the project designers for the calibration of safety work. The case study is the castle of Larciano, which has undergone restoration and securing in recent years. More specifically, the works involved the castle walls and its fortified gates. Public institutions, architects, engineers, and archaeologists were involved in the project. The first phase of the restoration project, in 2019, focused on the three fortified gates to the castle. In 2020 the project moved to the eastern section of the walls, which was threatened by a real risk of collapse. On both occasions, archaeological surveys and analyses had to be matched with the need for restoration. During the two phases of intervention, two different workflows were defined, due to the peculiarities of the structures: this confirms that survey of architectural heritage has specific characteristics that challenge the adaptation of archaeologists. For the three gates, 3D models were realized with a photographic campaign after the removal of vegetation from the buildings and before the scaffolding construction. At the eastern walls, the photogrammetric archaeological survey represented a challenge for the types of construction and the environmental challenges. A preliminary photographic campaign, with vegetation, had to be mixed with a second one without it but with the scaffolding. This meant a collection of more than 2000 photos, taken from less than a metre away. The processing phase was hard but successful, and with few adjustments a complete 3D model of this structure was realized, eliminating the scaffolding.

Keywords: *Building Archaeology—Photogrammetry—Restoration—Castle Walls*

CHNT Reference: Somigli, L., Marcotulli, C. and Cheli, F. (2025). 'Archaeological Documentation During a Securing and Restoration Project: An Example of Successful Approach: The Case of the Castle of Larciano (Pistoia – Italy)', *Proceedings of the 26th International Conference on Cultural Heritage and New Technologies*, Vienna and online, November 2021. Heidelberg: Propylaeum.
doi: 10.11588/propylaeum.1449.c20756.

Fig. 1. The fortress of Larciano a), and part of the eastern wall before the restoration b). Vegetation, collapses, safety precautions and the steepness of the ground are visible (© Chiara Marcotulli).

Larciano castle

The Medieval village of Larciano, in the province of Pistoia, is located on the western slope of Montalbano, a chain of hills that separates the plain of Florence, Prato and Pistoia from the lower valley of the Arno River (Valdarno), and that in the Middle Ages was controlled by the cities of Lucca and Pisa. In this period, Montalbano was a strategic frontier area: for this reason, numerous castles and fortified villages were built throughout the territory (for example Vinci).

At the end of the 11th century the Guidi counts, one of the most important and prestigious feudal families in Tuscany, fortified the castle of Larciano with the aim of dominating this strategic territory until defining, probably between the 12th and the first quarter of the 13th century, the district of the castle. In 1226 they sold the castle to the city of Pistoia.

Indeed, the castle of Larciano dominated the mountain pass of Montalbano which allowed the city of Pistoia to access a very strategic marshy area, called "Padule di Fucecchio", and the valley of the Nievole river (Valdinievole) from which, following the Arno, it was possible to reach the Tyrrhenian Sea. The Valdinievole area was crossed by a rather complex road network whose origin dates back, in part, to the Classical Age. The main route was the Cassia which connected Pistoia to Lucca. With the fall of the Roman Empire and the progressive abandonment of its road system, in the Early Medieval period, the Francigena route was added in this context, developed on a previous branch of the Cassia, which crossed the Valdinievole between Lucca and the Arno River.

Larciano, with its walls and fortress, is one of the best-preserved examples of a medieval fortified village. Its current conformation is the result of various construction phases between the 10th and 14th centuries. In this period, it passed from the control of the Conti Guidi to the city of Pistoia and finally to Florence. Each authority made changes to the structure of the castle, enlarging the walls, and fortifying the fortress, the result of which is still visible today (Milanese, Patera and Pieri, 1997; Quirós Castillo, 1999, pp. 127–140).

The current feature of the castle still presents clearly readable traces of the fortification from the Guidi's age and of the subsequent reorganization by the medieval Municipality of Pistoia (Figure 1). The trapezoidal fortress is located at the highest point in the northern part of the site and was restored in the 1970s. The walls, probably to be attributed to the reconstruction of the castle by the city of Pistoia in the 13th century, are preserved for one kilometre and along the route there are three gates, the two to the north dated to the 12th–13th century and the southern one probably built between the 15th and the 16th centuries (Quirós Castillo, 1999, p. 137).

The research and restoration project

The Castle of Larciano: Research, restoration and enhancement project, funded by Tuscany with a grant dedicated to the fortified town of the region, is a memorandum of understanding between the Municipality of Larciano, the Soprintendenza Archeologia, Belle Arti e Paesaggio of Florence, Pistoia and Prato and the University of Florence with the field collaboration of its professional spin-off, Laboratori Archeologici San Gallo. The restoration and securing of the city walls are the result of a virtuous collaboration.

All the institutions involved decided to plan the work by trying to conciliate safety requirements with the unrepeatable opportunity to conduct archaeological analyses during the operations (Valacchi et al., 2020). After an initial stage of intervention in 2019, focused on the three fortified gates to the castle, in 2020 the project moved near the fortress; works began on securing the eastern section of the walls, which was threatened by a real risk of collapse, also due to the difference in height between the inside and outside of the walls (over 10 metres). On both occasions, the decision was made to conciliate the need for restoration and safety measures with the carrying out of archaeological analyses that would allow us to deepen our knowledge of the construction techniques present and the construction phases that have taken place over the centuries. Survey, with 3D techniques, was part of the archaeological work since we consider surveying to be an important part of scientific research. For this reason, it is important that the critical process of graphic documentation is guided and possibly carried out directly by archaeologists. Survey construction and archaeological analysis proceed together and can benefit from each other (Drap et al., 2012).

Work planning and workflow definition

The overall workflow of the restoration project was settled during the first stage of the program, which focused on securing the three fortified gates of the castle. The main operations included the insertion of mortar between the stones of the walls and, in some cases, the partial dismantling of the precarious walls for their vertical reconstruction. It was therefore decided to proceed immediately with archaeological survey and stratigraphic analyses before the restoration changed the original appearance of the walls. Thus, in the first phase of the work, the succession of operations to be carried out was planned, to guarantee the best possible result, both from an archaeological and restoration point of view. The first operation was the removal of the infesting vegetation from the structures; then archaeological survey and stratigraphic analyses were carried out; finally, the scaffolding was erected, and the restoration work began.

As for the archaeological survey, it was decided to make a three-dimensional photogrammetric model (about these techniques see Remondino and Campana, 2014); considering the height of the artefacts, a camera mounted on a telescopic monopod was used to reach even the top parts. A Leica total station was used for accurate measurement of control points. This workflow proved to be effective in all interventions on the three gates, allowing complete archaeological documentation to be obtained and the restoration to be carried out on time. Moreover, during the restoration works the archaeologists intervened again. The work involved the use of scaffolding to reach the highest parts of the structures, which was used to refine the archaeological analyses by, for example, taking mortar samples from the portions attributable to the different construction phases and directly measuring certain building elements. Furthermore, in some cases a new photographic campaign was carried out to update the photogrammetric model: the restoration of the south gate had removed the soil deposit from the terrace that crowned the gate, revealing the extrados of the vault. It was therefore decided to also document this part that was initially not visible, and to include it in the general model (Valacchi et al., 2020).

Fig. 2. The scaffolding of the wall: the floors made it hard to obtain vertical overlap and it forced to take very close images (© Chiara Marcotulli).

Restoration of eastern walls: new answers to new problems

In the second stage of the work, focused on the eastern castle-walls, it was planned to operate according to the same scheme: cleaning of the vegetation, archaeological analyses and photogrammetric survey, erection of the scaffolding and execution of the work. However, it soon became clear that this workflow could not be applied: the cliff below, the height of the wall, and the trees close to it did not allow for a complete cleaning without first erecting the scaffolding. The problem was that the scaffolding would make it impossible to see the walls. As is often the case, the survey of architectural heritage has specific characteristics that challenge the adaptation, and creativity, of archaeologists to complete the work (to cite just one example of the different possibilities of architectural survey related to photogrammetry only, see Genin, 2019). It was therefore decided to carry out a first photographic campaign before the scaffolding, as well as the measurement of a series of control points with the total station. In the same way, the archaeological analyses were started, at least for the portions free of vegetation.

After cleaning the walls, it was still necessary to document the object in more detail, but the scaffolding represented a major obstacle for the photogrammetric survey: it was possible to shoot from no more than one metre away, on 7 different floors, with difficulty in overlapping the various floors due to the scaffolding planks (Figure 2). Obviously, the use of a drone was considered, but if before the removal of the vegetation it presented too high a risk of collision, after the cleaning of the wall and the erection of the scaffolding the situation was no more propitious: the safety of the scaffolding involved dense nets over the entire vertical surface. It was therefore not possible to shoot in front of the scaffolding with a drone.

On the other hand, it was possible to document the walls in their entirety, as the vegetation and soil deposits between the stones and above the top of the wall had been removed: this allowed us to show the elevation, the top and the thickness of the wall and a portion of its nucleus, thanks to the cleaning of a big lacuna.

Fieldwork

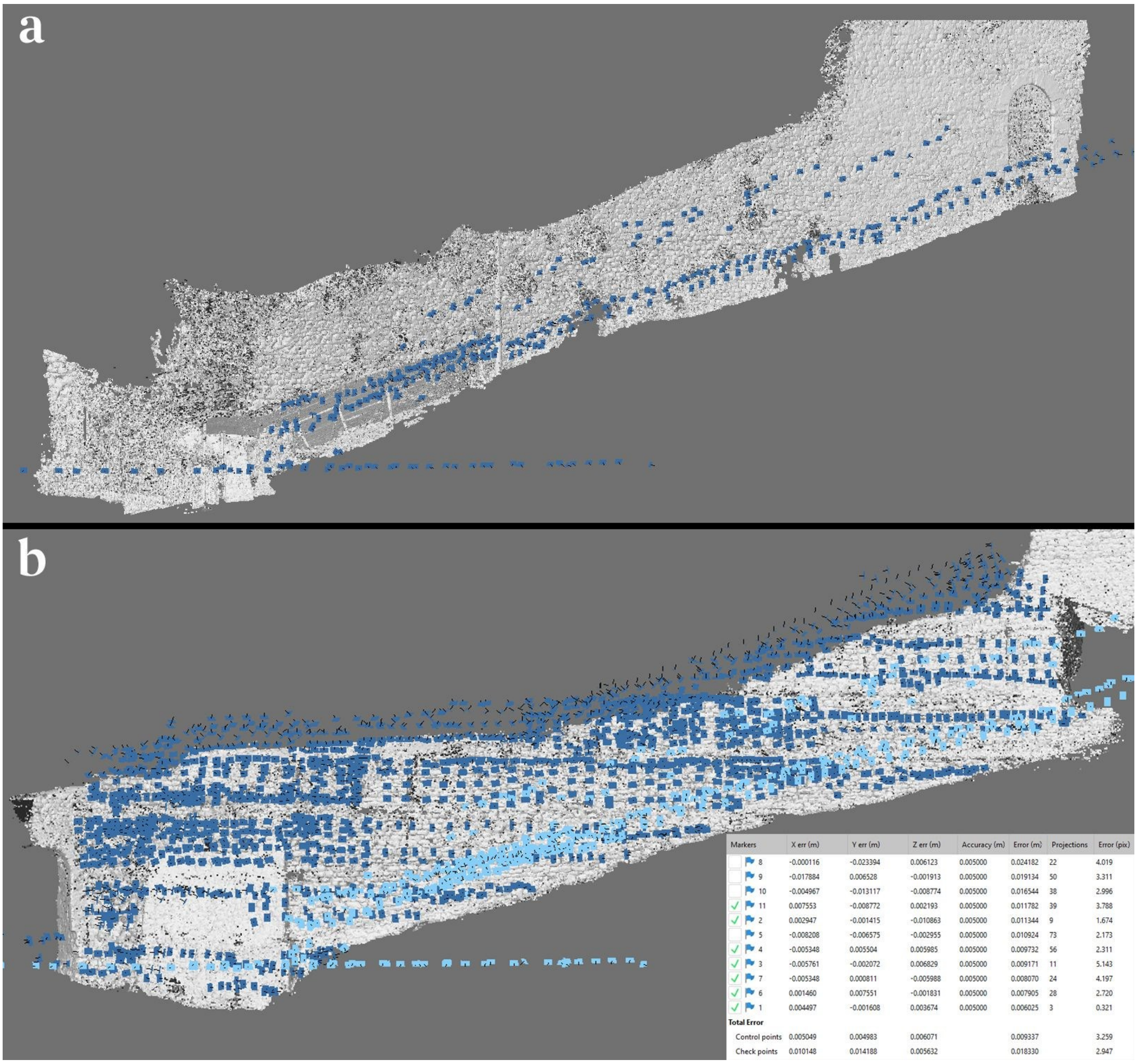
The photogrammetric survey was a real challenge, to be able to model the entire stretch under restoration: about 35 metres for a height of up to 10 metres. Comparing the preliminary photographic campaign, without scaffolding, and the final one, with scaffolding, some data emerge that allow us to evaluate the differences: in the first case, with photos taken from the ground and with the telescopic monopod, keeping about 3–4 metres from the wall (depending on the steepness of the ground), 259 photos were sufficient to cover the entire stretch. In the second case, 2335 photos were needed to model the same wall portion (Figure 3).

Photos were taken from less than a metre away (the width of the scaffold planking), and each photo covered an area of a few square metres. The structure of the scaffolding (poles, planks, protective netting) made it impossible to have a wider view.

For both campaigns the same camera was used, a Nikon D7100 SLR, 24.1-megapixel DX-format CMOS sensor and Nikkor 18-105 f/3.5-5.6 VR lens. To minimise the preparation phase of the images, an attempt was made to take advantage of a cloudy but bright day to take photos, to avoid sharp shadows from the scaffolding and to have the most uniform brightness possible. However, the priority was not to slow down the work site, so at certain times the work was carried out despite suboptimal light conditions. The reason is that the main objective was to document the structure in its pre-restoration condition, and to provide support for the archaeological investigations. The "aesthetic" rendering of the three-dimensional model was a secondary objective.

Processing

The sheer volume of images not only led to hardware problems with processing, but also with the orientation of the images, due to the poor overlap, especially vertically, because of the presence of the scaffolding floors. Metashape by Agisoft was used for the entire process; the opensource software CloudCompare was used to intervene on the dense cloud: cloud cleaning, comparison with the preliminary one, and subsampling to decimate the points.



Markers	X err (m)	Y err (m)	Z err (m)	Accuracy (m)	Error (m)	Projections	Error (pix)
8	-0.000116	-0.023394	0.006123	0.005000	0.024182	22	4.019
9	-0.017884	0.006528	-0.001913	0.005000	0.019134	50	3.311
10	-0.004967	-0.013117	-0.008774	0.005000	0.016544	38	2.996
11	0.007553	-0.008772	0.002193	0.005000	0.011782	39	3.788
2	0.002947	-0.001415	-0.010863	0.005000	0.011344	9	1.674
5	-0.008208	-0.006575	-0.002955	0.005000	0.010924	73	2.173
4	-0.005348	0.005504	0.005985	0.005000	0.009732	56	2.311
3	-0.005761	-0.002072	0.006829	0.005000	0.009171	11	5.143
7	-0.005348	0.000811	-0.005988	0.005000	0.008070	24	4.197
6	0.001460	0.007551	-0.001831	0.005000	0.007905	28	2.720
1	0.004497	-0.001608	0.003674	0.005000	0.006025	3	0.321
Total Error							
Control points	0.005049	0.004983	0.006071		0.009337		3.259
Check points	0.010148	0.014188	0.005632		0.018330		2.947

Fig. 3. The 3D models of the eastern wall: the result of the preliminary photographic campaign a), with indication of the position of the cameras (the blue points), and the result of final surveys b), realized from the scaffolding (in light blue the disabled photos reused by the preliminary campaign). The different distribution of cameras to cover the same wall is obvious. Bottom right, the table of references with the indication of errors (© Lapo Somigli).

After initial processing of all the photos, a difficulty emerged in reconstructing the entire structure from the photos taken from the 7 levels of the scaffolding: not all the photos were correctly oriented and only some sections of the wall were reconstructed. At that point the possibilities were two: to process the wall in separate portions, corresponding to different levels and then try to register the partial models, or to find a way to allow the software to process the entire model together. The second way was chosen. A successful solution was the use of some photos of the preliminary campaign, to facilitate the orientation of all images. As mentioned, these photos were taken from further away and were therefore useful for linking the stripes of the various levels, providing a wider overlap. Obviously, the photos showed a partially changed artefact, since the wall had been cleared of vegetation and debris, but they were still useful for the purpose of orienting the images.

The recognition of control points was also a challenging processing step, as each image covered a few square metres of the wall. The control points were recognisable points on the stones of the wall. Due to the height of the masonry, it was not possible to use coded targets. Making the recognition of the control points even more complicated was the fact that they had been identified and measured before the cleaning of the wall and recognised on large images. Therefore, several references to orientate between the portions of the masonry were lost and finding the points on such narrow photos was very time consuming. In this case too, the preliminary photos were very supportive.

Once the image alignment and scaling processes were successfully completed, the panoramic photos from the first campaign were excluded from the next processing steps to avoid incorrect or ambiguous reconstructions.

Another time-consuming processing step was the cleaning of the dense point cloud. Numerous extraneous elements were present, in particular poles, planks and scaffolding nets. As they were also very close to the wall, removing them without affecting the wall took a long time.

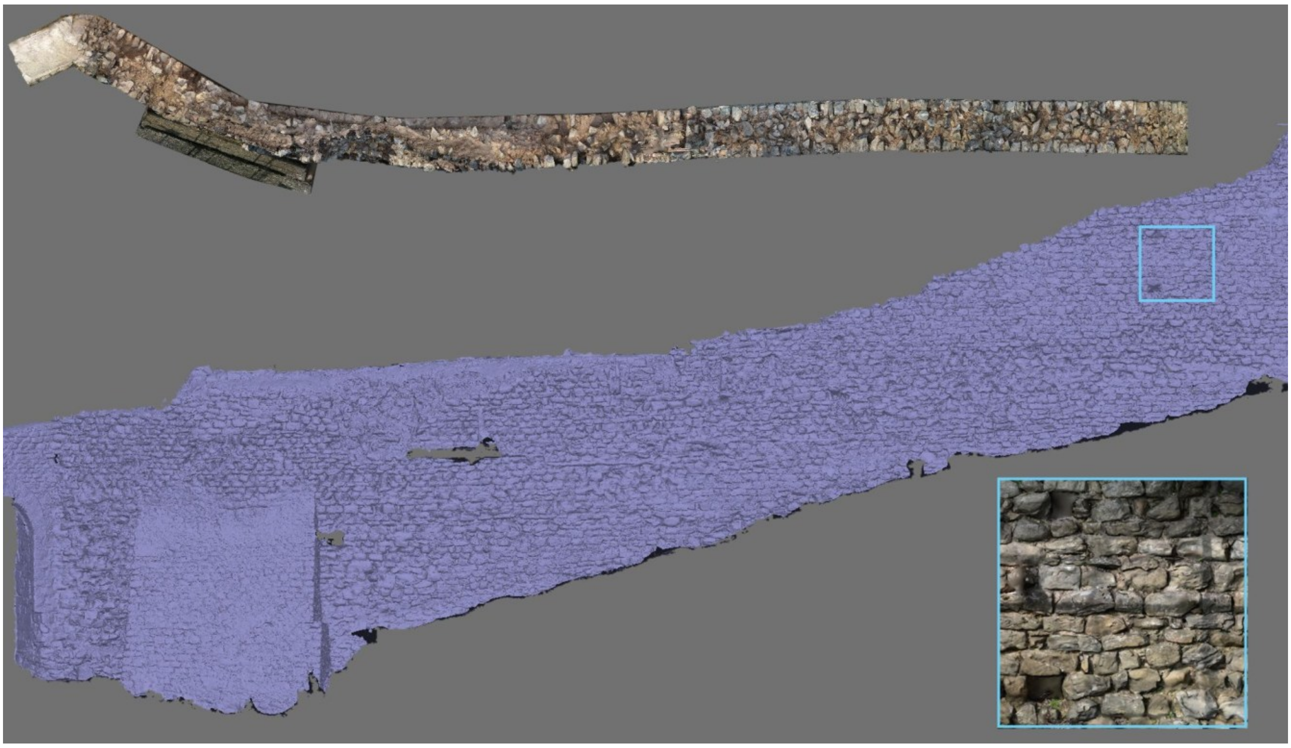


Fig. 4. Top and front view of the final model. Bottom right, a detail of masonry texture. Some shadows due to scaffolding structure are still visible (© Lapo Somigli).

This operation was carried out both by using the Metashape tools and by exporting the dense cloud to Cloudcompare. A possible alternative was to mask the scaffolding elements on the photos, but this was discarded because this operation could take longer than cleaning the point cloud and the most difficult elements to be removed were very close to the wall.

At the end of the processing, the model was composed of approximately 39 million faces, based on a point cloud of approximately 435 million points (Figure 4). Its accuracy proved to be more than acceptable, with a verified average error of approximately 0.02 m. To verify the error, two parameters were evaluated: the values calculated by Metashape software for the individual CPs, and the use of some markers measured with the total station as check points instead of control points. Finally, two external control measurements, not included in the Metashape process, were used to verify the accuracy.

Since the final model was the result of photos with poor overlap, another check was made regarding the accuracy of the reconstruction of the geometry of the structure. With the help of CloudCompare software, the final model was compared with the initial one, which, although lacking in detail due to the vegetation, had good geometric reliability. The overlap of the two models made it possible to verify that the final model also maintained the correct geometries (Figure 5).

To confirm the effective coordination between the archaeological operations and the restoration site, the survey was finally integrated as the work progressed: the top portion, which was only brought to light in greater depth at a later date, was documented and included in the general survey. On the other hand, the three-dimensional survey made it possible to evaluate the profile of the wall at every point, to better calibrate the safety intervention.

In fact, as the work progressed, such an accurate survey also proved useful for the project designers. It was used to identify the most compromised and misaligned parts of the wall, where the risk of collapse was greatest. This made it possible to recalibrate the securing work in order to achieve a more effective result.

Conclusions

The project is still ongoing and will hopefully see further work carried out to restore and enhance this valuable but still little-known site. The completed phases have already fulfilled the objectives of conciliating archaeological research with safety and restoration. The photogrammetric survey was the best possible choice to carry out the archaeological research: without this type of survey, it would not have been possible to investigate and document the construction phases of the castle-walls, while at the same time maintaining an overall view of the structure and such a high level of detail.

The photogrammetric survey also proved useful for the securing and restoration project, not only for archaeologists. It has also been an interesting case study for developing ad hoc operational methods for each intervention. The context in which the work was carried out represented a rather extreme and experimental case: the same operation of photogrammetric documentation, nowadays consolidated and widely used, was a challenge that required specific adjustments and variations to the ordinary workflow. We had to apply a specific workflow to each building: this confirms that archaeological survey obviously has its own rules, but it is not repetitive. Critical analysis of the artefact is fundamental, and it is often necessary to be able to adapt procedures to the context.

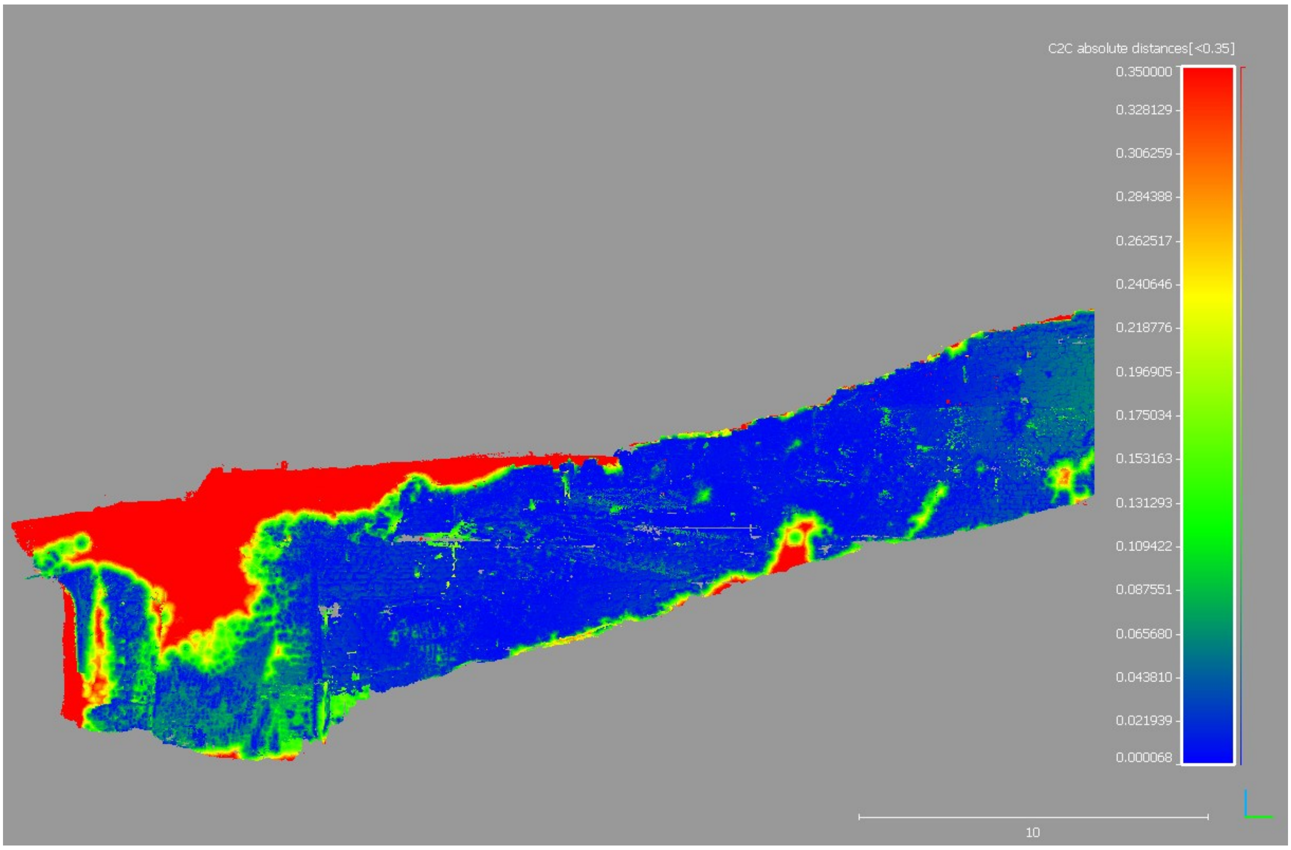


Fig. 5. Result of the distance computing between the preliminary model and the final one. The blue areas (distance close to 0) demonstrate the coherence between the two models; the green and red zones (increasing distance from 0, red means more than 35 cm) are concentrated only where the wall was covered by vegetation during the preliminary campaign (© Lapo Somigli).

This case study has also confirmed that 3D surveying is not only a way of documenting and presenting data, but a methodology that acts directly in the research phase (Drap et al., 2012). Finally, the survey process in the field was carried out directly by the archaeologists, allowing measurement and interpretation operations to go hand in hand.

Looking to the future, the hope is that the castle of Larciano will still be the subject of new actions for protection and enhancement, as one of the most important and best-preserved medieval sites in central Tuscany. Indeed, the partial three-dimensional models made so far (a section of the walls and the fortified gates) could be the basis for a wider project of documentation and musealization of the castle. One outlook is to cover the entire site with a medium-resolution survey (with low-altitude shooting by UAV), on which high-resolution models of the preserved medieval structures would be inserted. If such a model is then enriched with the historical-archaeological information collected during the research, it could represent a great added value for the promotion and enjoyment of the site, even remotely.

It is also wished that the synergy implemented in Larciano between different actors – research institutions, local public authorities, and commercial enterprises – and the working method tested here will be a useful example for similar projects focused on the restoring and enhancement of the walled fortified town and villages of Tuscany (and Italy), whose conservation and managing is often problematic for local administrators.

Conflicts of Interest Disclosure

No potential competing interests have been reported by the authors.

Author Contributions

Conceptualization, Writing – original draft, Writing – review & editing: Lapo Somigli, Chiara Marcotulli, Francesca Cheli
Data curation, Formal Analysis, Validation, Visualization: Lapo Somigli
Investigation, Methodology: Lapo Somigli, Chiara Marcotulli, Francesca Cheli
Project Administration: For The Restoration Project: Municipality of Larciano; For The Archaeological Analysis: Chiara MARCOTULLI
Supervision: Guido Vannini

References

Drap. P. et al. (2012). *Photogrammetry for Medieval Archaeology. A way to represent and analyse stratigraphy*, *18th International Conference on Virtual Systems and Multimedia*, pp. 157–64. Milan, Italy: IEEE, doi: 10.1109/VSMM.2012.6365920.

Genin, S.M. (2019). Photogrammetry: methods of survey and applications on restoration works, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W11, pp. 557–564, doi: 10.5194/isprs-archives-XLII-2-W11-557-2019.

Milanese, M., Patera, A. and Pieri, E. (1997). 'Larciano. Museo e territorio'. Rome, L'Erma di Bretschneider.

Quirós Castillo, J.A. (1999). *La Valdinievole nel Medioevo. "Incastellamento" e archeologica del potere nei secoli X-XII*. Pisa: ETS.

Remondino, F. and Campana, S. (eds) (2014). *3D Surveying and Modelling in Archaeology and Cultural Heritage. Theory and Best Practices*, Oxford: Archaeopress (BAR International Series, 2598).

Valacchi, E., et al. (2020). 'Le mura di Larciano Castello. Studi e risultati di un restauro', *Tutela & Restauro 2016.2019, Notiziario della Soprintendenza Archeologia Belle Arti e Paesaggio per la città metropolitana di Firenze e le province di Pistoia e Prato*, pp. 171–178.