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Pietrabuona fortress

Image-based models for archaeological dissemination

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Abstract: The subject of this paper is the ancient church of San Matteo, built in "La Rocca", in the medieval settlement of Pietrabuona (Pescia, Pistoia, Italy). This ancient building was built in the XI century and was transformed into a fortification in the XV century, during the battles between Pisa and Florence, but since then it has been abandoned and reduced to ruin. The elaboration of data obtained thanks to a digital survey and the interpretation of such information done by a multidisciplinary research staff have made possible not only the analysis of the distinctive, typological features of the church, but also the analysis of the implementation criteria and stylistic elements that characterize the building. The 3D models are gradually becoming an essential resource for those working in the heritage field, because they introduce potentially innovative applications in the areas of dissemination and preservation: they can be seen as repositories of a variety of data (metric, materic, static, historical, etc.). Starting from laser scanner and digital photogrammetry data through to increasingly refined optimization procedures, it is now possible to obtain a 3D image with greater metric and perceptive reliability in addition to a significant reduction in hardware necessary for visualization. Once a high detail model is well-defined (high-poly), the pipeline presented in this case study allows for the creation of scale models with simplified geometry (low-poly), using the reverse modelling process and modelling techniques taken from the entertainment field. These models, conveniently mapped with normal displacement maps and diffuse colour textures, are characterized by high perceptive fidelity easily visualized on laptops, tablet and smartphones, not to mention the enriched information extremely useful for the analysis a building.

Keywords: Pietrabuona, laserscan, digital photogrammetry, image-based modeling, dissemination, heritage.

Introduction

The focus of this paper is on San Matteo, an antique church built on a site called *La Rocca* within the mediaeval village of Pietrabuona (Pescia, in the province of Pistoia, Italy).
The building is situated on the extremity of a rocky spur, controlling an old route connecting the castle with the nearby village of Medicina.
The church, constructed in the 11th century, was converted into a fortress in the middle of the 15th century during the conflicts between Pisa and Florence.
Towards the end of the 14th century the *fortress-gate* system became a key feature of the final city wall. Over the centuries with the decline in importance of the defensive walls, the fortress was abandoned and reduced to ruins (fig. 1). The state of advanced decay in the building made a mapping campaign necessary,

to be able to accurately document it and start a programme of conservation, enhancement and promotional operations based on solid knowledge.

Integrated survey

The fundamental basis for any project of preservation and improvement on a heritage site is its documentation through integrated mapping systems. Here the word “integrated” describes the modus operandi, both the use of tools and procedures to acquire diversified data relative to dimensional, morphological, technological aspects as well as the state of decay and static instability. A multidisciplinary approach has been adopted throughout the study. Such conditions are of paramount importance in order to compile a thorough knowledge base.

After an initial phase of acquiring on-site data, thanks to digital mapping, and to the subsequent phase of 2D and 3D representation, the interpretation and processing of such information was carried out by a multi-disciplinary team whose work enabled the interpretation of typological characteristics, building criteria adopted and the stylistic aspects characterizing the structure, not to mention the monitoring of decay causing the state of degradation.

After being properly analysed, all information collected in this phase was stored in the relative database capable of correlating historical, archaeological, artistic, iconological and iconographical content. The survey campaign was carried out using a Faro 8080 Photon 120 laser scanner and a Leica TS02 total station, creating a topographic reference mesh to be used in the following phase of recording the scan settings (fig. 2)

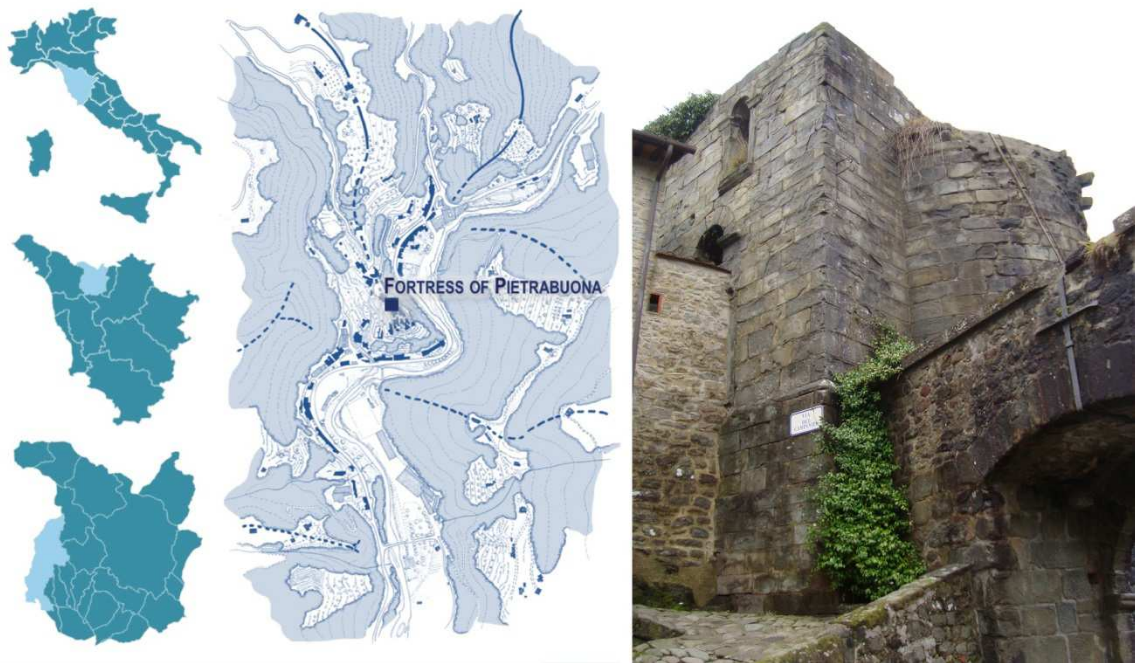

Fig. 1 – Territorial of Pietrabuona and a view of the fortress.

Fig. 2 – Integrated survey of the fortress.

The above data, together with results from direct survey and subsequent photogrammetric survey, have created a significant mass of information capable of documenting in great detail the building.

The use of passive detectors has played a significant role in this study. Through the application of available photogrammetric software, this technology creates dense point clouds from photographic images. Despite various constraints regarding,

1. the necessary lighting conditions for carrying out effective photographic images (these should be as homogeneous as possible)
2. the techniques adopted to obtain images that cover the whole surface of the building (avoiding shadows as much as possible),

such a method offers advantages largely due to the speed the mapping itself is carried out (this becomes more apparent, the smaller the size of the building), to the low costs involved and to the fact that polygonal models constructed with data coming from point clouds already display textures of the diffuse colour.

In the survey campaign, digital photogrammetry is used to integrate those gaps caused by the impossibility of the scanner's light beam reaching the object, thus allowing for the correct completion of the geometric description of the buildings. In addition, the 3D models generated with this method have been used to carry out the monitoring of buildings both from the point of view of structural instability and superficial decay (fig. 3).

Concurrently, with the acquisition of metrical and material data of the existing structure through research of sources from historical archives, it has been possible to reconstruct the evolution of the building over the centuries.

Founded in the 11th century, San Matteo carried out its religious functions until the middle of the 14th century. This does not exclude a possible defensive role right from the beginning up to the turn of the 13th and 14th centuries due to its strategic position bordering the dominions of Pisa and Florence.

Nevertheless, it is highly probable that this change in usage of the building coincides with the castle coming under the Florentine sphere of influence during the 14th century.

Traces of this change are still evident today amongst the ruins of the building: for instance, on what remained of the church, exploiting where possible the pre-existing walls still intact, the new ruler erected a control tower in conjunct with the castle gate which leaned up against the foundations of the apse (fig. 4). Despite the substantial modifications undertaken to transform the church into a defensive garrison, characteristic stylistic and structural features can still be detected confirming its religious nature such as the presence of a single nave, the horse-shoe apse, crown corbelling with mouldings and the total absence of bichromy. Even though these elements recall some of the stylistic peculiarities used in religious architecture in the Apennines around Pistoia - the size of the nave is a clear indicator of the influence from Lucca – a recent study of features unfamiliar to the area, shows a strong similarity to those elements found in structures around the city Grosseto.

Fig. 3 – Photographic campaign and construction of models using photogrammetry.

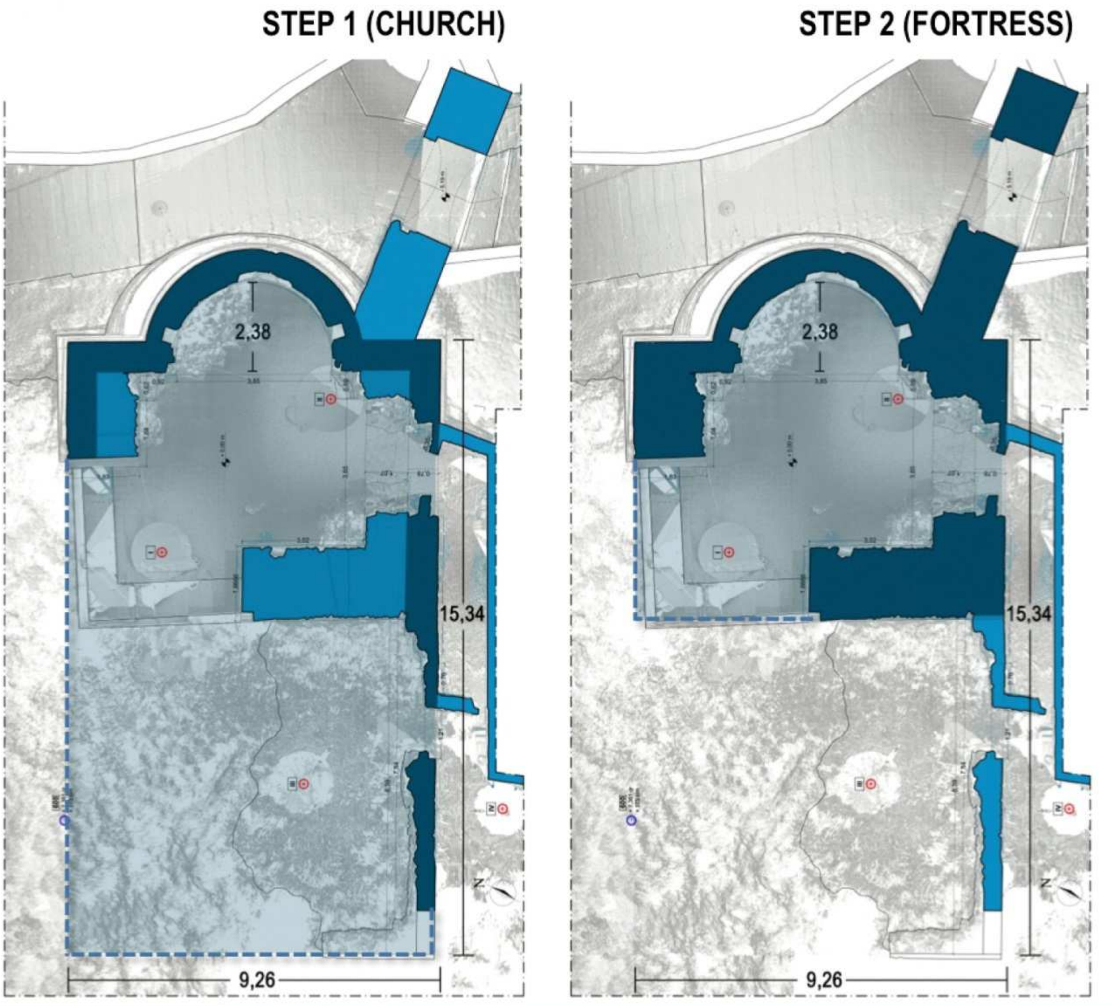

Fig. 4 – Superimposition of the structure of the church (step 1) and tower (step 2).

This may suggest that the erection of the church on an important communication route of the time was connected to hospital orders (mainly the Guglielmiti) active both in the Apennines and Southern Tuscany - a hypothesis still being researched.

From a structural point of view, the building is characterized by stone walls using squared blocks in horizontal, parallel rows of uniform height on the inner and outer walls with a rubble masonry infill. The precision of the work carried out is seen not only in the use of the pseudo-isodomic technique, but also in the meticulous finish applied to the surface of the blocks which are smooth and squared.

The remaining portions of the tower were, on the other hand, built using different building techniques featuring the use of smaller and irregular fragments (fig. 5).

Fig. 5 – Styling characters of the fortress.

Modelling and texturing

Increasingly 3D models represent a fundamental resource for those working in the field of cultural heritage bringing into play new job potentials linked to the propagation and conservation of national heritage. Indeed, these models can be seen as containers of not only metrical and textural information but also data pertaining to static stability and historical archives.

Fig. 6 – Pipeline for the construction of models using data from laser scanner.

Through the adoption of increasingly sophisticated methods of optimization, it is possible today to obtain, starting off with data from active sensors, elaborated 3D models which offer greater metrical and perceptive reliability using slightly lesser hardware for visualization.
To create these models, a consolidated pipeline is utilized, which exploits information technology originating from diverse fields of application: instruments specialized in reverse modelling permit the definition of a highly detailed model (high-poly) and quality control of the mesh generated whilst checking for eventual topological errors; software developed in the entertainment area provide tools which allow for the creation of small scale models from simplified geometry (low-poly) whilst at the same time managing bitmap images necessary for texturing (fig. 6).
In the case shown here, the mapping system of low-poly models plays a central role, as it represents the philosophy the entire procedure is based on. It comprises the encoding operation of the geometrical data of the high-poly model inside bitmap images, which, once applied to the simplified model are able to perceptually produce a very detailed image of the architecture mapped.
Thus, such models – appropriately decimated, maintaining the deviation from the high-poly model within a defined range, and mapped with a normal map or displacement map and diffuse colour texture – stand out for their high perceptive reliability and can be easily visualized on laptops, tablets and smart phones in addition to being supplied with useful information regarding the understanding of mapped objects (fig. 7).

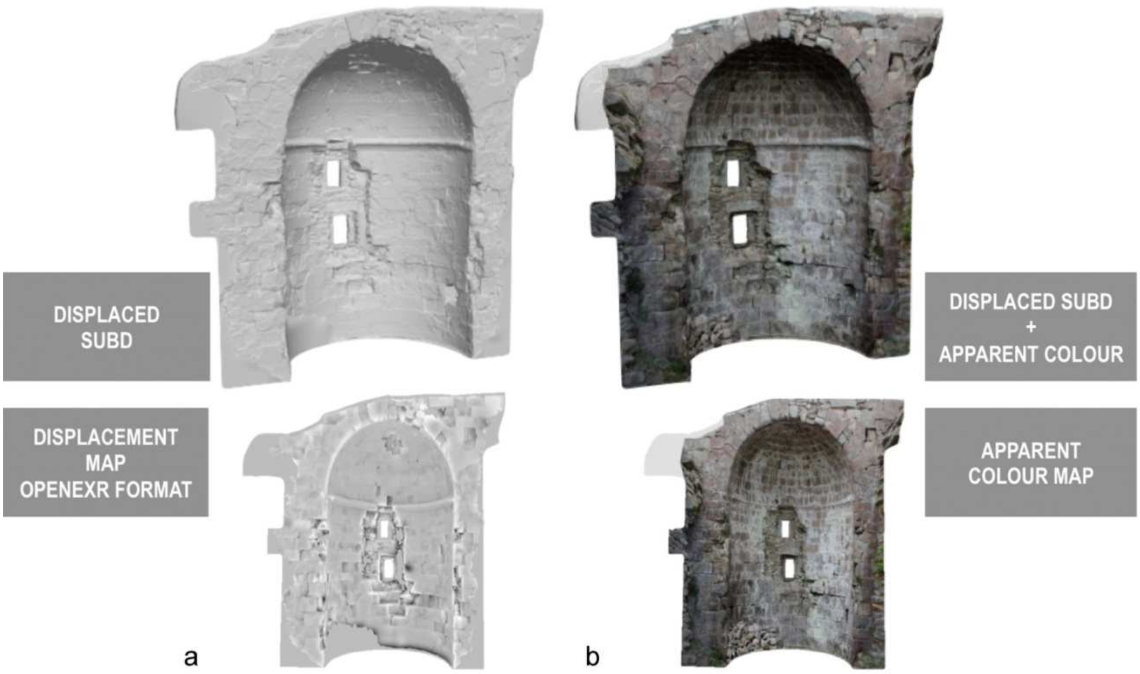

Fig. 7 – The models texturing: a. Normal map, b. Displacement map.

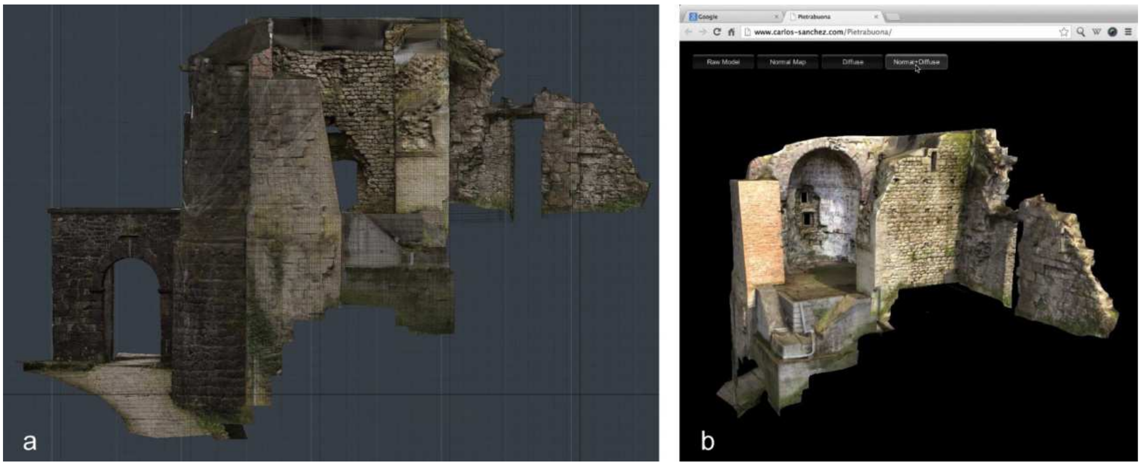

Fig. 8 – Application of real-time for dissemination: a. the optimized and textured model; b. the model shown in the Unity Web Player.

Dissemination

There are multiple uses of 3D reality-based models, both in the scientific community and with the general public. To begin with, our cultural heritage must be brought to the attention of the general public, so the vastest number of people can enjoy it, at least virtually. In this particular case, the web has proven a fundamental instrument, giving everyone the chance to gain useful information regarding a building or monument without having to visit the site in person. 3D reality-based models allow the user not only to view and navigate for example a building in real-time, but also to explore its volume, actively interacting with it acquiring information such as size, geometry and state of preservation (fig. 8). In addition, thematic textures applied to the model can transform all technical analyses and interpretations regarding buildings, into something immediate and attractive: the findings of archaeological studies, the layout of masonry stratigraphic unit (MSU), the graphic display of chronology concerning parts of the building are all elements which can be shown, overlaid and correlated.

Similarly, the outcome of the diagnostic phase focusing on eventual restoration work and consolidation can be visualized. In the case of the Rocca such analyses have led to the identification of a series of causes of the degradation arising from diverse factors; at times environmental, linked to climatic conditions and the

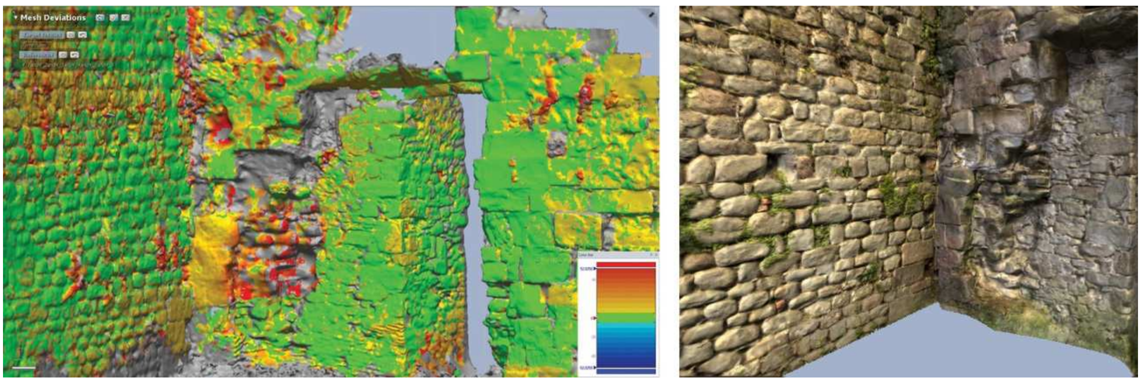

Fig. 9 – Control and monitoring through the comparison of reality based models.

characteristics of the underlying terrain; at times biological or manmade. Such factors have caused structural instability, cracks, and episodes of saline efflorescence, bacterial colonization or vegetation infestation.
It is of extreme importance to stress how in this case study, integrated techniques of digital photogrammetry and reverse modelling, have been as an effective means of recording and monitoring the structural degradation of the building due to factors of instability. Through digital photogrammetry it has been possible, in little time and at low cost, to produce 3D models of the ruins which are highly reliable in terms of textural and geometrical authenticity (margin of error no greater than 1 mm) and which have been aligned and compared to 3D models derived from reverse modelling procedures applied to the acquired data during the mapping process with the laser scanner.
This comparison, made possible thanks to systems able to measure mesh deviation, has revealed both the minutest signs of instability in the composition of the wall masonry as well those of greater importance including the lack of entire stone blocks (fig. 9). Finally, it is worthwhile evaluating the role reality-based models play in the planning and design phases, processing and visualizing recovery and cultural heritage renewal programmes.

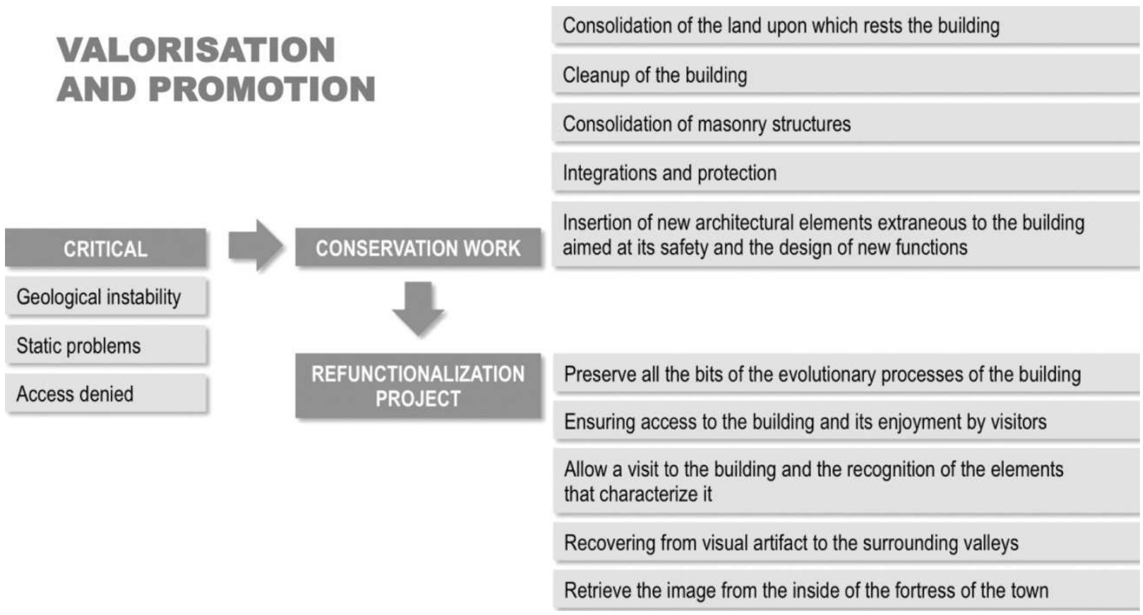

Fig. 10 – Guidelines for valorisation and promotion of cultural heritage.

Valorization

Being firm believers of the fact that there is no better way of safeguarding our cultural heritage than through its use, the following proposals have been put forward with the initial aim of facilitating access to the building and secondly, to guarantee its use, compatible with its specific characteristics.
The restoration project tackles two main issues: first, protecting the actual building, which calls for various interventions aimed at eliminating signs of decay along with their causes; secondly, accessibility. Such operations are necessary as the building presents clear evidence of structural instability and is in a deplorable state of degradation, making it currently inaccessible (fig. 10).

At the moment, the Rocca commands a unique view over the Pescia river basin with its historic paper mills dotted alongside its course. The relationship between the multiple and reciprocal perspective views generated over the centuries, has not only tied the Rocca to its territory but also to its inhabitants: from Via di San Rocco one can enjoy the monumental outline of the church's apse in pietra serena, whilst climbing up the paths, winding through the houses, sporadic glimpses of the structure come into view, gradually revealing the church little by little. Based on these assumptions, the first project hypothesis proposes the introduction of a single volume placed at a height lower than the ruins of the tower base, so as not to impede the view of the Rocca, but at the same time allowing access to, and use of it. The principles on which the conceptual design is based are to be found not only in the suggestions proposed by the surrounding natural landscape, but also on the current physical state of the Rocca which such an intervention would highlight the modifications to the structure in the past. With this in mind, the restoration of the church's original ground plan is envisaged with the addition of a

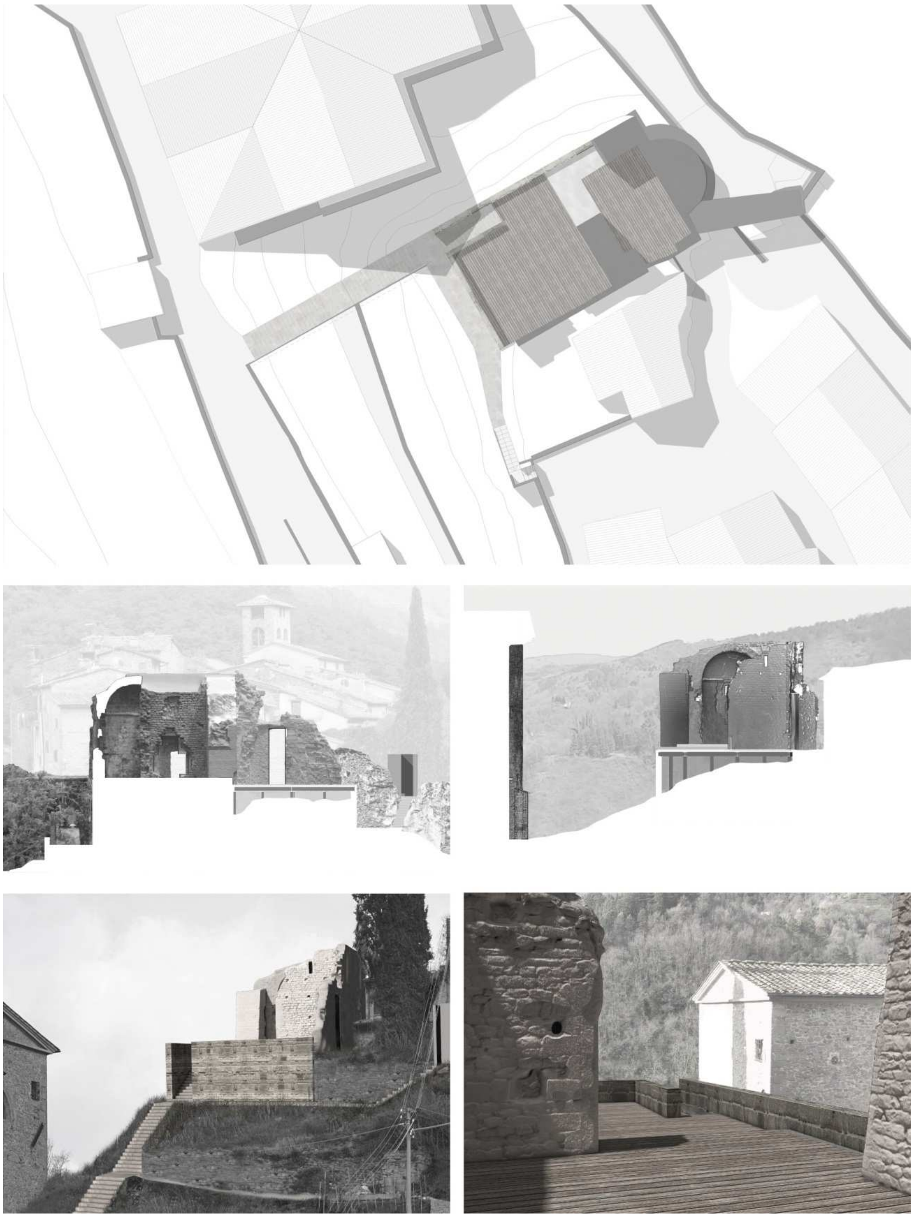

Fig. 11 – Project for development: hypothesis 1 (S. Basile, L. Fantacci, G. Lazzari, A. Luci, I. Russo, M. Sangiovanni).

volume superimposed. The floor space thus created would respect the original size and geometry of the church and would fill in the void left by the collapse of the underlying terrain (fig. 11).
The second proposal based on the same assumptions, takes advantage of contemporary architectural language and compares pre-existing historical evidence in the transformation process of the building. Again in this case, the project aims at rehabilitating the historical memory of the religious building through the reconstruction of the layout of the floor plan, but with the introduction of steps, aimed at evoking the function of the watch tower, for which the structure was used from the 14th century onwards. The present open space has once again become public domain and as in the previous example, is used as a place to contemplate the surrounding landscape (fig. 12).

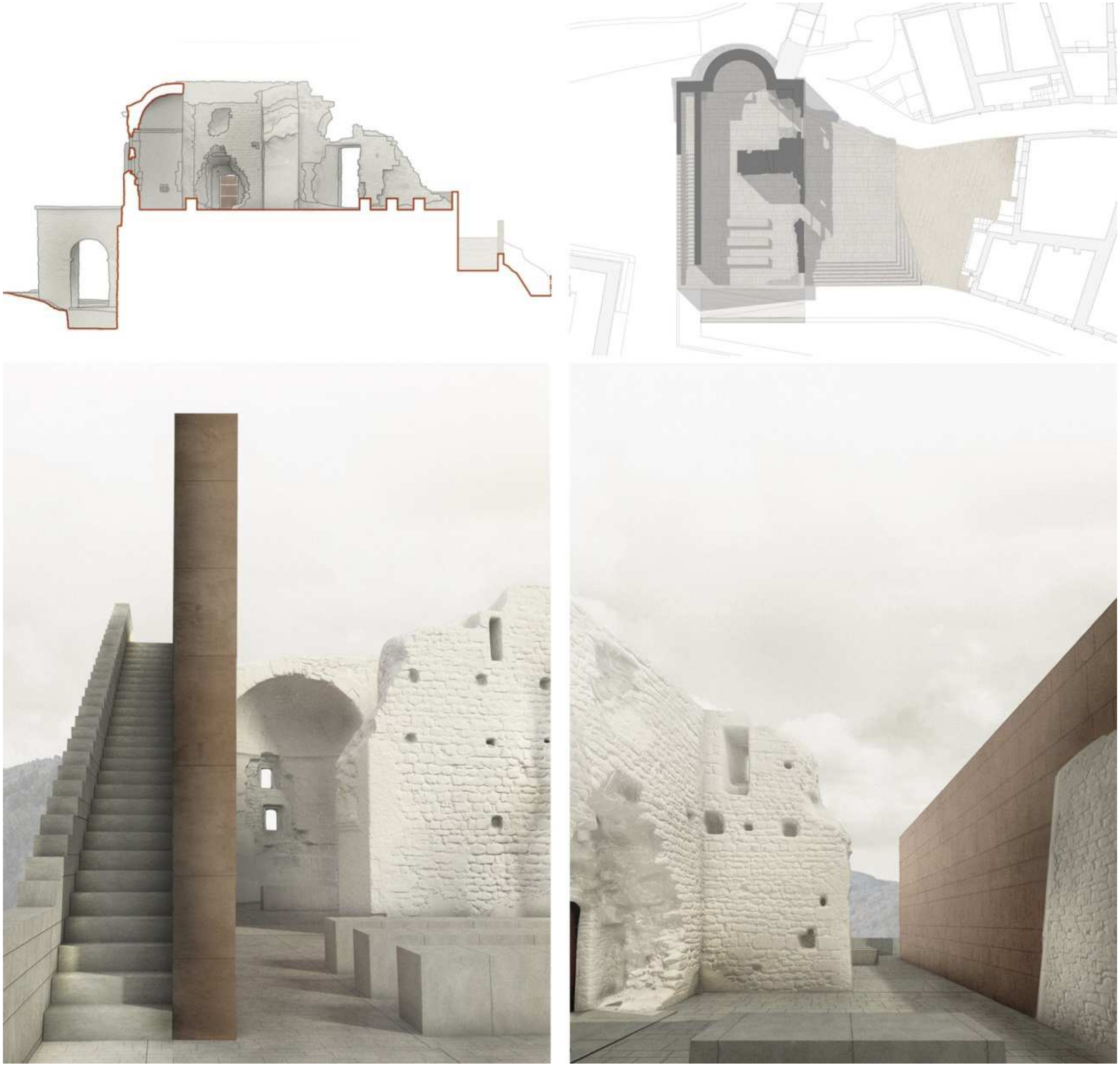

Fig. 12 – Project for development: hypothesis 2 (G. Francesconi, S. Laghi, V. Ronzini).

The third project attempts to restore the functionality not only of the Rocca but also of the space in front, which was once the main access gate to the early church. To reclaim the churchyard, the demolition of a structure adjoining the Rocca is envisaged. This building due to subsequent extensions and alterations over time has encroached what remains of the old façade. The removal of this element, in part responsible for the decay of the walls, and a stone fence surrounding it, would allow for the redesigning of the walking surface in the churchyard, creating additional open space, which would be linked to the other areas reopened to the public within the original perimetre of the church.

An underground room, easily recovered in eventual consolidation work on foundations, could house the necessary, illustrative material concerning the building, providing ready, on-site information on the various aspects linked to the history of San Matteo (fig. 13).

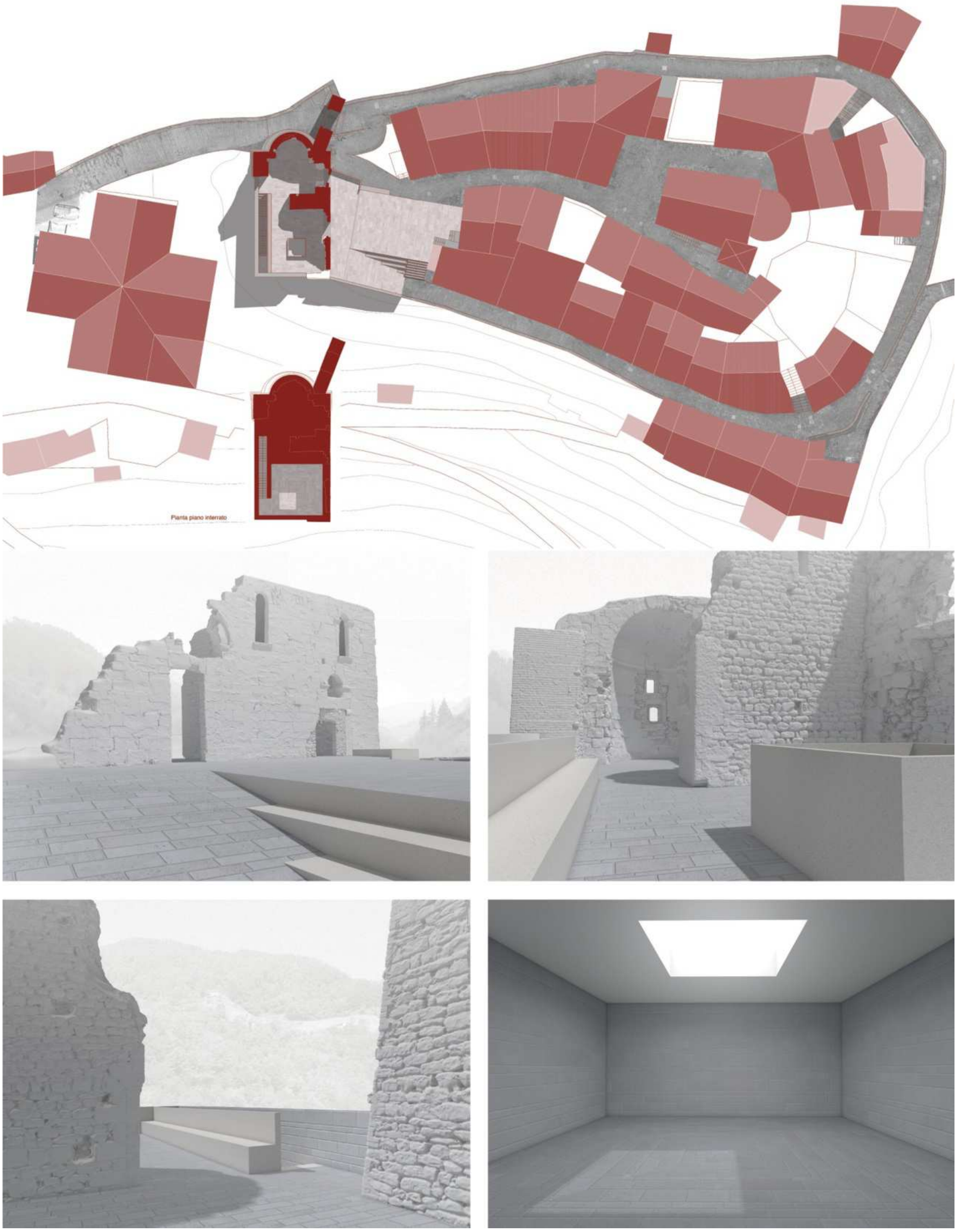

Fig. 13 – Project for development: hypothesis 3 (A. Aliperta).

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