

sous la direction de  
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# Villages et quartiers à risque d'abandon

*Stratégies pour la connaissance,  
la valorisation et la restauration*

TOME 1

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DEGLI STUDI  
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Tunisie, village berbère de Zriba el-Alia (© L. Hadda)

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**Cultures pour la  
conservation et la  
valorisation du  
patrimoine à risque  
d'abandon en Italie**



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# THE DIGITAL DOCUMENTATION OF THE MOUNTAIN VILLAGE OF ROCCA RICCIARDA: BETWEEN MEDIEVAL AND MODERN ARCHEOLOGY

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**Axonometric  
view of the  
laser scanner  
point cloud  
of Rocca  
Ricciarda.**

**Matteo Bigongiari**  
Università degli Studi di Firenze-Italia

Rocca Ricciarda is a mountain village located on the slopes of Pratomagno, in the municipality of Loro Ciuffenna (AR). In medieval times the site was known to be part of that system of fortifications necessary for the control of mountain passes: the fortress of the village, known since 1191, later became the property of the Guidi Counts; today only the archaeological remains remain, on a rocky spur at the entrance of the village, recently brought to light by excavations conducted by the University of Florence. In 2017 started a research aimed at creating an archive of morphological and three-dimensional data: that data documented the architecture of the historic village, which was completely rebuilt after a fire after the Second World War. The documentation of the historic village was created by planning a campaign of instrumental surveys that reconstructed the entire three-dimensionality of the historic village: both range-based acquisitions with laser scanners and image-based acquisitions were conducted for the creation of accurate three-dimensional models of the architectures, through SfM procedures. This paper reconstructs the various phases and methodologies used for the registration and quality certification of three-dimensional survey data; the graphic restitution process of the two-dimensional technical drawings, which describe the morphology of each building that forms the village, has been particularly deepened. Material information has been added to the technical drawings thanks to the elaboration of accurate orthoimages of each facade of the buildings. The village has also been represented in its landscape value by creating environmental sections, on a general scale, useful for describing the morphology of the territory and the attention paid to creating the mountain settlement.

**Keywords:** Architectural Survey; Laser scanning; Photogrammetry; Urban Survey, Mountain village

## Introduction

In 2017, following an agreement signed between the Department of Architecture of the University of Florence and the Municipality of Loro Ciuffenna<sup>1</sup>, which derives from a collaboration relationship that led to deepen some research on the municipal area, a research : the research aims to create an archive of morphological and three-dimensional data documenting the architecture of the historic village of Rocca Ricciarda, in order to update the information on the buildings of the mountain village with modern range-based instrumental survey technologies.

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<sup>1</sup> In this regard, the digital survey of the Pieve di Gropina is recalled, a theme that can be explored in Bertocchi et al. 2019.



**View of the mountain village of Rocca Ricciarda.**



**View of the mountain village of Rocca Ricciarda, and of the Arno Valley.**

The use of tools such as laser scanners and the participation of the University of Florence would have provided an important research opportunity, with the aim of deepening the methodologies for documenting landscapes and mountain villages. These settlements, following the recent and gradual abandonment of the inhabitants in favor of the most promising job opportunities offered by the major centers, also need from the point of view of the local administration a strong help so as not to leave abandoned villages that they have been an important point of life for the mountain landscape for hundreds of years.

The documentation of small historic centers is a topic that has affected the DiDa from various points of view, such as for the planning of historic centers following the earthquakes that have strongly hit central Italy in the last decade<sup>2</sup> (Bertocchi 2013).

In the same way, the University of Florence has been working for several years to make this settlement process evident to the students of the architecture course, and in the last decade it has dedicated important efforts to documenting these realities, using mountain villages as a place of exercise for young students and future architects: this has given them the possibility in this way both to approach and become aware of the theme of mountain villages and the theme of three-dimensional and massive documentation.

Some of the results of this research can be explored in studies relating to the historic

<sup>2</sup> It is precisely in the case of surveys in emergency conditions that this technology has brought an enormous improvement, allowing to quickly obtain the three-dimensional reconstruction of urban aggregates to assess their state of instability.



Casentino villages, which several times have gone beyond mere documentation trying to integrate small projects to bring a contemporary architectural language into the traditional and vernacular mountain architecture (Pancani 2020).

### **Brief History**

The history of the settlement of Rocca Ricciarda can be traced back to the entire second millennium of our era, embracing the entire period from the Middle Ages to its inclusion in the Republic of Florence; the medieval history of the village is particularly interesting due to the close connection with one of the main Tuscan comital families, the Guidi, whose architectural testimonies have been the subject of an in-depth study by the University of Florence, from an archaeological and documentary point of view (Vannini 2009), including the territorial conquests that reached the upper Valdarno between the tenth and the end of the twelfth century, in close relationship with the events of Romagna. The expansionist policies of the Guidi counts, closely linked to the establishment of landed properties, the control of the main monastic complexes (Bertocchi et al. 2011) and other forms of land management in depth within the conference held in Poppi (Collavini 2003).

This expansion system includes the acquisition of the Rocca Ricciarda castle, in the process of defragmentation of the guiding estates in the Valdarno territories today part of the municipality of Loro Ciuffenna (Repetti 1833-1845).

The works carried out in recent decades by Tuscan universities have greatly contributed to clarifying the process of Enclosure of the Casentino and Valdarno, analyzing the surfaces of the structures, the masonry, as if they were a real palimpsest that succeeds through medieval



**View of the laser scanner survey** in the archeological remains of the Rocca.

**A section of the laser scanner point cloud**, that shows the complexity of the ground levels.

archaeological analyzes, to shape the structures of the period. From the expansionist point of view, the presence of numerous castles in this area is given precisely by the nature of the border of the territory, the first area of expansion chosen by Florence since the thirteenth century. The area around Loro Ciuffenna and the Pieve di Gropina was an important settlement point connected by the ancient Roman road network to the rest of the settlements in the Valdarno area: the ancient Cassia was in fact the main route of medieval settlements (Vilucchi 2002), which connected to the most important Italian centers.

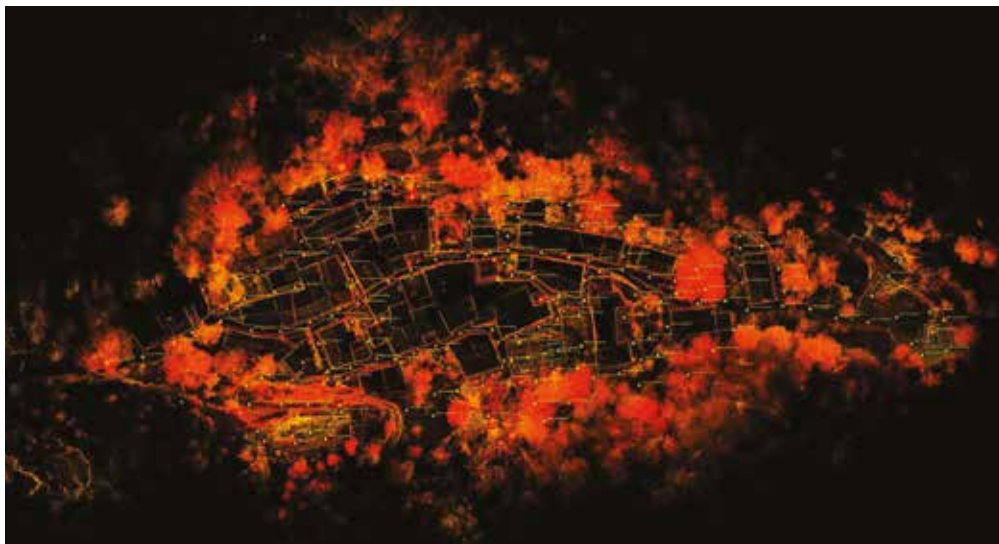
Gradually the settlement system of Rocca Ricciarda has evolved losing its defensive functions; through the centuries it first passed under the control and influence of Florence, but there are no obvious changes until the Napoleonic era, when an ossuary was added outside the village for hygienic standards, which is still visible downstream. Due to the destruction during the Second World War, the village was completely rebuilt by the inhabitants; today most of the buildings are in a good state of conservation, having no more than 70 years of new life but are singularly uninhabited.

Methodologies for surveying the mountain village



**Top view of the laser scanner point cloud** of Rocca Ricciarda.

For the creation of a digital archive of data describing the morphology of the historic village, it was decided to rely on range based and image-based technologies in order to map all the surfaces of the existing buildings. In this paper we will clarify the methodological



protocols and the choices made to reach a metrically reliable final technical design, which has been a line of research in the digital survey sector for many years<sup>3</sup>: in fact, since the protocols on the acquisition and management of point clouds, the research was aimed at improving the methodologies and using them according to the different purposes of the survey. The state of the art of research in the documentation sector now requires the use of laser scanner instrumentation in order to create a database of morphological information that is complete and continuously updated: the point clouds constitute an information database that testifies to what the places are like at the moment of acquisition of measurements, in the same way as a photograph; It is now common practice to analyze, in the case of previous three-dimensional scans, the data historically collected<sup>4</sup>.

The laser scanner survey of the Rocca Ricciarda village required an acquisition campaign that lasted about a week, dedicated not only to obtaining all the scans necessary to reconstruct the three-dimensionality of all the buildings present and all the unevenness of the ground, but also for educational purposes for the group of students of the Architecture Survey course<sup>5</sup>: the students, divided into working groups, were entrusted with the task of draw-

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<sup>3</sup>To learn more, see Pancani 2017.

<sup>4</sup>This made it possible to monitor the evolution of architectures over time, in the same way as an archive of satellite images as we can find on online opensource platforms.

<sup>5</sup>The acquisitions took place within a seminar of the Architectural Survey course held by prof Stefano Bertocci, a.a. 2016/2017.





**View of a plan with texture**  
of one of the blocks in Rocca Ricciarda.



ing up a first survey on sight of each aggregate of the settlement, subsequently deepening with collected measures, through traditional survey systems and photographic shots necessary for the realization of three-dimensional models through automatic photogrammetry procedures, the morphology of individual buildings. In fact, from a purely didactic point of view, it is still considered essential to train the student through direct knowledge of the building, which remains somewhat extraneous through digital survey techniques, which do not allow direct contact with the structures.

The creation of the digital scan archive was achieved through the use of quick acquisition instrumentation, which has been repeatedly tested in many massive and rapid acquisitions in other missions within the research group (Bertocci et al. 2017): specifically, the measurement operations were carried out with a ZF Imager 5006h laser scanner<sup>6</sup>. To complete the data acquisition campaign, in this case four days of field work were planned<sup>7</sup>; thanks to the intrinsic characteristics of the laser scanner and point cloud management software, it was preferred to design a survey consisting of many scans, with a high margin of overlap<sup>8</sup> with each other. The survey project involved scanning the entire town of Rocca Ricciarda, paying particular attention to the environmental characteristics of the area around the settlement. At the same time, it was considered important to document what was left on display of the archaeological remains of the medieval tower.

Two different scanning resolutions were selected depending on the portion of the city to be detected. For the analysis of the tower and fortification, where the description of their materiality is important for the purposes of archaeological readings and in any case of the documentation of the historical heritage, it was preferred to perform scans at a high resolution level, while for the part of the city that develops outside the defensive system it was decided to obtain a lower level of detail; the distance between two station points has never been greater than 10m, in order to maintain an excellent percentage of overlap between the scans and to describe all surfaces with an acquisition mesh not exceeding 1.5 cm. The planning of the laser scanner survey did not involve the use of targets or control points, the data acquisition proceeded quickly, and it was possible to carry out a very large number of laser stations (over 100 per day) by the hand of a single operator. A total of 350 scans were made that covered the entire area of the historic center: this data, as well as being a documentation tool for the village, is functional to the compilation of the future filing of buildings<sup>9</sup>. In fact, the design of

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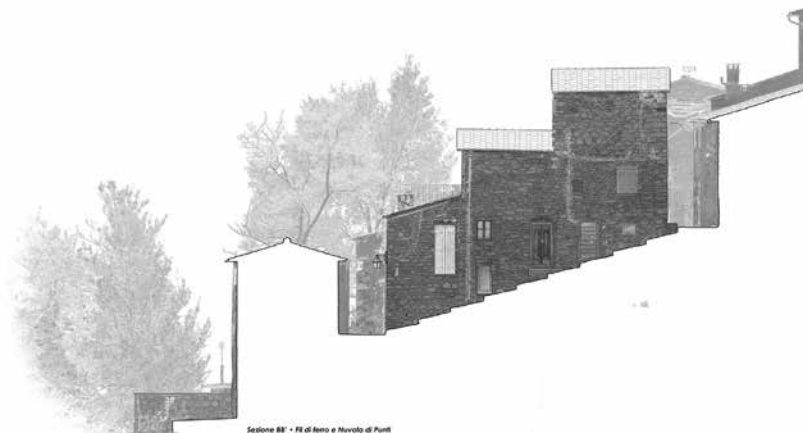
<sup>6</sup>The instrument was provided by the DiDA Survey Lab.

<sup>7</sup>The main features are very fast scan times, up to 1000000 pt/s, and a nominal acquisition range up to 78 meters.

<sup>8</sup>The scans have been designed to have a margin of overlap of at least 25% between one station and the next.

<sup>9</sup>The laser scanner survey was conducted and coordinated by the writer, both in the acquisition phase and in the registration phase.





reassembled by experimenting with two different joining methods: through the manual ro-to-translation of one scan on the other (visual alignment), or through the automatic reconstruction of the positioning of the stations (autoalignment). The visual alignment method is a reinterpretation of the cloud-to-cloud reassembly system, in both systems, taken two contiguous scans and with a good margin of overlapping of points, a cloud constraint is obtained that binds the two stations. The substantial difference between the two systems lies in the fact that previously (cloud-to-cloud) the operator had to select at least three homologous points in the two scans to have a pre-alignment, sometimes a cumbersome operation, while with the more modern system you simply rotate one scan on the other until the points match. Autoalignment, on the other hand, allows you to automatically merge multiple laser stations that have a very high percentage of points in common; to facilitate the calculation of the software, it is possible to indicate in advance which scans are consecutive, among which scans create links, to prevent it from trying all possible combinations. Basically, the two systems produced a similar result, it should be noted however how the automatic recognition of the scanning station has always been successful where the scans had a higher resolution, probably due to the greater number of points in common given by the density. surfaces close to the instrument location.

Once the general point cloud of the historic center has been recorded, the survey certification phase, i.e., registration validation, is followed<sup>13</sup>. To ensure the correctness of the gener-

<sup>13</sup> The instrumental reliability of the single scan is known from the laser scanner specifications, however, outside the methodological protocols developed within universities, there is still no certification system for the registration phase of the point cloud.

al model, numerous vertical and horizontal sections were carried out to verify that the points from different scans overlapped correctly without misalignments not tolerated by the restitution scale. The analysis of the section profiles made it possible to establish that the general point cloud is reliable.

During the data collection campaigns for the purposes of the survey, photographic acquisition of the areas of interest cannot be neglected. The data coming from the camera integrates the morphological information coming from the “metric” survey of a series of important characteristics for the understanding of the urban space and which cannot be described through a technical drawing. First, an adequate photographic survey of the buildings allows to document the actual state of the places, allows the operator to describe the architectural composition of a building or the relationship between two buildings even after some time and far from the place of investigation.

The main contribution of photography to the survey consists in describing all the material information of the buildings; this type of data is fundamental for the preparation of urban plans aimed at the recovery or conservation of urban aggregates, the drafting of the so-called color plan, intended as a coordination tool for all those interventions aimed at the conservation and enhancement of the architectural, urban and environmental components, which combine to form the overall image of an urban aggregate.

The materiality of the buildings can be intuitively described with the two-dimensional photoplan graphics: in this way it is possible to quickly visualize the chromatic and material relationships that exist between adjacent buildings and between an appropriate range of plasters<sup>14</sup>. With the return of the material data, not only the materials with which the buildings or architectural elements are composed are highlighted, the photographic archive provides a precise and accurate survey of the current conditions of conservation of the surfaces of the urban fronts; on the basis of these data, it is possible to identify and catalog the problems related to the surface conservation of the facades and produce thematic documents concerning the diagnostic analysis of surface degradation, thus managing to quantify the damaged surface units. Investigations on the state of structural conservation also require clear photographic documentation as support where it is possible to understand the damage and how it was caused.

With the most modern computer systems and starting from technologies dedicated to the automatic recognition of objects and people in a frame, the three-dimensional image-based modeling systems have finally been developed, based on the automatic

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<sup>14</sup> in this case, a careful study on the reliability of the photographic data (color study) becomes appropriate, see Gaiani 2015.

recognition of common pixels between multiple frames and on the spatial reconstruction of the camera's grip points for the creation of a textured model. This spatial reconstruction methodology, correctly defined SfM (Structure from motion), does not strictly fall within the principles of photogrammetry, it does not lead back to measures of objects but to their three-dimensionality, not based on metric measures: it is possible to obtain complex models of architectures without enter or know any measure, obviously the result will not refer to any metric scale.

The images acquired to obtain three-dimensional models must first of all comply with a certain degree of definition required by the final rendering scale of the drawing; the sensors of the cameras easily reach high definitions (over 20MP per image), this can lead to obtaining datasets that are too redundant and difficult to manage (unless you have very performing calculation stations), or on the contrary, with photos that are too general, not adequately defined with reference to the return scale<sup>15</sup>. In order to allow a correct matching between the frames it is necessary that the acquisitions are as clear as possible and without out-of-focus areas: for this purpose it is important to know the characteristics of the lens well, how it responds according to the variation of the aperture or the shutter speed.

To correctly describe the three-dimensionality of the objects, every single surface must be taken from different angles in several photographs to allow the 3D reconstruction. In order to obtain a texture that is as homogeneous and adequately defined as possible, it is important that all the frames are sharp and that they have the same px / cm ratio on the objects to be represented as much as possible; it is also important that the photographs are taken in the same period of time: exposure of different lights and different shadows during the day, as well as complicating the first phase of alignment, do not allow to obtain a correct texture from the point of view of color rendering and definition.

## Conclusions

The three-dimensional survey thus acquired made it possible to create accurate two-dimensional drawings that represent all the aggregates, with floor plans and plants at different scales, deepening up to the scale of 1:50. All the elevations have been returned both by wire and by integrating the material information that comes from the ortho-photoplanes: all these works followed the restitution process described in the previous pages.

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<sup>15</sup> In general, for representations on a scale of 1:50, such as those set for the historic center and required by both urban planning and restoration work, the definition ratio to be guaranteed during the acquisition of the frames is 6 px / cm. Compare Pancani 2017.

The construction of a three-dimensional archive and two-dimensional surveying works have made it possible to provide adequate documentation of the village, hitherto missing; at the same time, the creation of the archive will allow for further studies on the digitization and sharing of the information acquired, in line with the main directions of research in the field of architectural representations.

The capture of a general three-dimensional point cloud of the entire architecture of the village can allow to create an accurate three-dimensional mesh model of the entire mountain village, integrating evident lacks of instrumental data of the roofs, which can be used both to better understand the three-dimensional development of the village, built on the slope of the mountain, from a technical point of view, both to set the morphological basis for the development of virtual fruition systems.

In addition to the documentation of the mountain village, which is facing a phenomenon of gradual abandonment, the creation of three-dimensional databases can be the starting point for creating a virtual museum system of the archaeological excavations present on the site, which can attract thanks to their tourist value. attraction to the strongest presence of visitors, because the village is located at the end of a driveway, therefore reachable only if there is a real desire to visit it. The documentation of the archaeological excavations can also be a further technical document which, if shared with the school of archeology, can serve as a useful tool to verify, or integrate information relating to the structures that have remained in evidence of the fortress that gives the site its name.

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Villages et quartiers à risque d'abandon sont aujourd'hui une problématique commune à des nombreuses régions de la Méditerranée, considérée comme un point stratégique dans les nouvelles politiques européennes. L'abandon progressif des zones internes est une constante dans les pays caractérisés par le sous-développement économique, avec les phénomènes d'émigration et de fragmentation du patrimoine culturel. Cela entraîne des problèmes d'architecture et de gestion du territoire. L'objectif principal de ce travail de recherche est de créer un espace de discussion qui comprend l'étude du patrimoine architectural et du paysage ainsi que les témoignages démo-ethno-anthropologiques.