Terrestrial and UAV based infrared thermography for mapping and investigating the humidity of historical buildings. The case of the Castle in Calvello.

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Terrestrial and UAV based infrared thermography for mapping and investigating the humidity of historical buildings. The case of the Castle in Calvello.

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Abstract. Humidity is one of the most frequent causes of damage to the architectural heritage. An effective and non-invasive way to detect the presence of humidity and identify the possible causes, from capillary rise to infiltration and condensation, is infrared thermography. The paper shows and describes the results from terrestrial and UAV-based (Unmanned Aerial Vehicle) thermography for understanding the cause-effect mechanisms of infiltration humidity in some halls of the castle of Calvello (in Basilicata), some of them characterized by walls paintings. The analysis of the acquired data allowed us to understand the nature of the damage caused by humidity and water infiltration in the castle structures, and to be able to put in place a plan for risk mitigation and damage resolution.

1. Introduction

The solution of problems related to humidity is a fundamental preparatory action to the architectural restoration. In fact, humidity is one of the most frequent causes of damage to the architectural heritage. Decay resulting from humidity needs to analyzed and characterized by means of cognitive investigations and precise analyses, including instrumental ones, to make a correct diagnosis and to plan the remediation intervention. An effective and non-invasive way to detect the presence of humidity and identify the possible causes, from capillary rise to infiltration and condensation, is infrared thermography.

The thermograms image and map the temperatures of the surfaces of the materials and the possible presence of cooling or heating processes. Surface evaporation of humidity from damp walls is always present if the relative humidity of the air is less than 100%. Evaporation is an endothermic process, so it removes heat from the surface of the wall (as well as from the surrounding environment) which in the thermographic image is usually colder where humidity is present [1,2].

The effectiveness of thermographic imaging depends not only on the characteristics of the cameras, in terms of geometric resolution and thermal sensitivity, but also on the extension of the areas investigated and the number of points of capture of the thermal images. In the latter regard, the traditional thermography integrated with the acquisition of thermal images conveyed by drones opens up new extraordinary perspectives of investigation for the analysis of the state of conservation and the monitoring of buildings and architectural monuments [3,4].

The integration between terrestrial and drone based thermography allows the multiscale observation of the building to be investigated and the map of external and internal surfaces, providing useful information not only to characterize the effects but also to identify the causes of humidity [4–13].

The paper shows and describes the results from terrestrial and UAV-based (Unmanned Aerial Vehicle) thermography for understanding the cause-effect mechanisms of infiltration humidity in some halls of the castle of Calvello (in Basilicata), some of them characterized by walls paintings. T

The castle is the result of a long construction history that starts from the 11th century (as evidenced by a document of 1089) which the first nucleus, consisting of a tower, dates back to [14]. In the Swabian and Angevin ages (XIII-XIV century) the castle was enlarged, taking on an architectural layout set around a courtyard. In the Swabian period, the castle of Calvello was one of the 29 castra and domus regi in Basilicata of the Statutum de reparation castrorum issued by Frederick II around 1240 [15].

In the 15th century the castle passed into the hands of the Sanseverino (important family in southern Italy), who were succeeded by the Carafa family in the 16th century and finally, at the end of the 18th century, the Ruffo di Calabria, who remained in possession of the castle (transformed into a palace) until the beginning of this century [14].

2. Material and Methods

The castle of Calvello had significant humidity infiltrations inside, which endangered the frescoes preserved inside. For this reason, the study included (i) a top-down analysis using a UAV equipped with a thermal imaging camera and RGB camera to create a visible orthophoto/thermal infrared map and a 3D model of the structure, and (ii) a ground-based analysis, inside and outside the building, using a high-resolution thermal imaging camera.

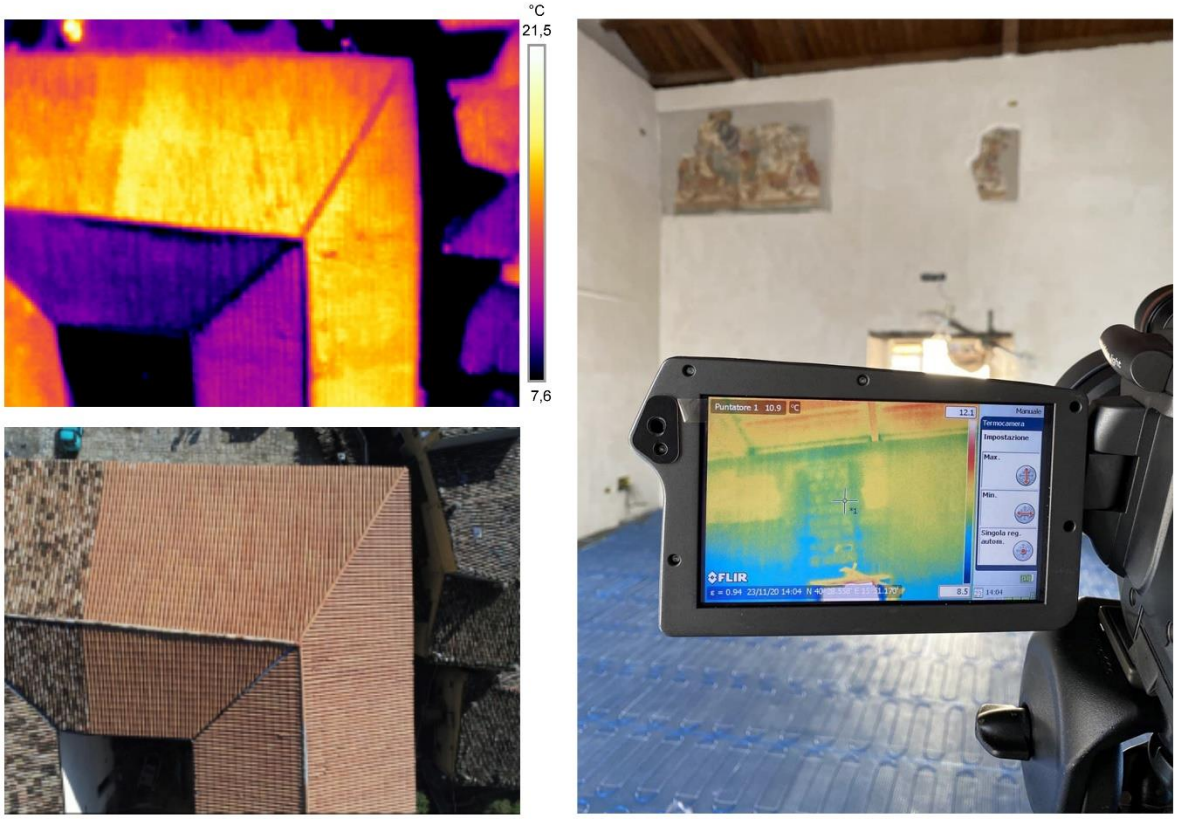
The drone used for the analysis was a Parrot Anafi Thermal, equipped with a FLIR Lepton 3.5 thermal camera (160x120) and a high-resolution RGB camera that allows optimal fusion between photos in the visible spectrum and those in the thermal infrared, thanks to software optimisation.

The terrestrial analyses, on the other hand, were carried out using a FLIR thermal imaging camera (640x480).

The acquisition was made during the morning and included the analysis of the roof, from above, and of the walls of the entrance and interior rooms, from the ground.

The data were processed using software (i) FLIR Tools+ for thermogram analysis and photomosaic creation, (ii) Agisoft Metashape for the creation of the three-dimensional model (Structure From Motion - SFM) and aerial orthophoto maps. The three-dimensional model was useful to understand the exact

location of the analysed rooms in relation to the roof and the identified problems (fig. 1).



(a) (b)

Figure 1 - (a) aerial photography acquired by drone (visible and thermal), (b) thermogram acquired with high-resolution FLIR in one of the castle's frescoed rooms.

3. Results

The analysis of the acquired data allowed us to understand the nature of the damage caused by humidity and water infiltration in the castle structures. Aerial photographs and thermograms acquired by drone show the damage to the roofing apparatus, consisting of tiles. The damage was mapped in the images and divided into two categories: (i) gaps (lack of tiles), and (ii) beginning of gap or crack.

The hot spots in the image represent the points where there is a lack of tiles, thus exposing the underlying part of the roof structure.

The analysis of the position of gaps and cracks and the analysis of thermograms from UAVs, combined with that of terrestrial acquisitions, made it possible to reconstruct the course of humidity and water inside the roof structures, up to the frescoed rooms. Moisture and water accumulated at the base of the roof pitches and from there reached the top of the walls in two ways: (i) through the cracks and gaps, as can be seen from the streaks at lower temperatures, below them, in the thermograms (especially fig. 1); (ii) due to a probable malfunction of the gutters that cause the water to accumulate and overflow towards the wall, not discharging the flow properly to the ground (fig. 2).

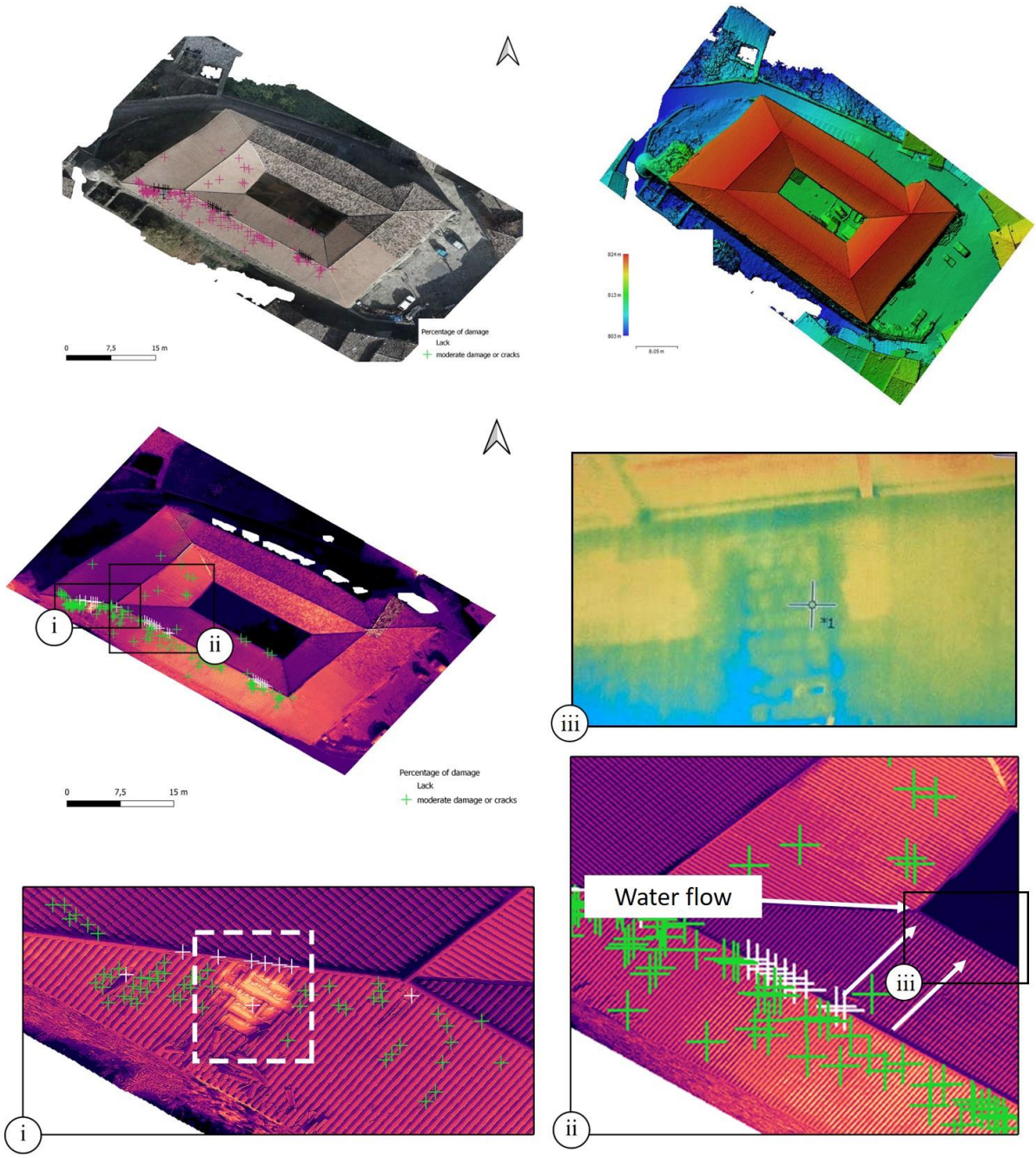


Figure 2 - Outputs obtained from UAV survey (RGB orthophoto, thermal orthophoto, and Digital Elevation Model) with identification of critical issues in the castle roof. (i) zoom on area where the tiles are missing; (ii) zoom on the area affected by the probable malfunctioning of the gutter; (iii) thermogram of the inside-wall of the castle.

4. Conclusion

The integrated thermographic analysis from the ground and from drone, with the creation of a 3D model to increase the knowledge of the spaces and to analyse the slopes, has proved to be extremely useful in

the case of the Calvello castle and, in general, has already proved to be very useful in other contexts in the field of monitoring applied to Cultural Heritage. The integration of different techniques and different points of view, in cases similar to the one presented, is a fast and effective solution for the identification of areas at risk and allows to acquire data from multiple points of view, having a complete picture of the state of art of the monument.

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