Enhancement of the information content available from non invasive diagnostics for restoration and knowledge of architectural heritage

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1. Introduction

The usefulness of the information produced by science and technology for the knowledge of the cultural heritage depends on the quality of the feedback and, consequently, on the “cultural” distance between scientists and end-users. In particular, such a distance is related to the end-users’ capability of transforming the knowledge produced by diagnostics with regard to:

1) information on both cultural objects and sites (decay patterns, vulnerability, presence of buried archaeological remains);
2) decision making (management plan, conservation project, and excavation plan).

From our experience in the field of the cultural heritage and namely the conservation of monuments, we noted that there is a relevant gap of information between professionals (geophysicists/physicists/engineers) and end-users (conservators/historians/architects). This gap is due to the difficulty to interpret “indirect data” produced by non invasive diagnostics (i.e. radargrams/thermal images/seismic tomography etc...) in order to provide information useful to improve the historical knowledge (e.g. the chronology of the different phases of a building), to characterise the state of conservation (e.g. detection of cracks in the masonry) and to monitor in time cultural heritage manufacts and sites.

Some experiences suggest different approaches aimed at making the interpretation of diagnostics and remote sensing easier, particularly by means of:

• Integrated application of novel and robust data processing methods;
• Augmented reality as a tool for making easier the interpretation of non invasive investigations for the analysis of decay pathologies of masonry and architectural surfaces;
• The comparison between direct data (carrots, visual inspection) and results from non-invasive tests, including geophysics, aims to improve the interpretation and the rendering of the monuments and even of the archaeological landscapes;
• The use of specimens or test beds for the detection of archaeological features and monitoring of monuments and sites.

In this short paper, we will show and discuss the results obtained in three case studies, already individually published [Masini et al. 2010; Leucci et al. 2011; Gabellone et al. 2013].

The first case study is related to the Cathedral of Matera, where investigations performed by GPR were aimed at characterizing the inner structure of two pillars by exploiting the available data provided by a coring (Masini et al. 2010). In the second case study, related to the Cathedral of Tricarico, an integrated approach based on the use of GPR and sonic prospecting for detecting...
cracks and inhomogeneities in the inner structure of masonry building elements [Leucci et al. 2011] was afforded. Finally, augmented reality has been experienced to make easier the interpretation of GPR prospections carried on the floor and walls of the chapel of the Holy Spirit in Lecce [Gabellone et al. 2013].

2. Cathedral of Matera: the inner of the pillars

The first case study is a poly-style pillar which bears the triumphal arch of the presbytery of the Cathedral of Matera, in Basilicata, remarkable monument of the Romanesque architecture in Southern Italy. The pillar has been investigated by GPR to understand its internal structure, which is important in order to investigate its preservation state, also in relationship to safety issues. The GPR prospecting has been carried out in 2007, in the framework of a NDT investigation campaign for the restoration of the cathedral. The availability of the data provided by a coring facilitated the interpretation of the reflections observed from the migrated radargrams. Such approach
allowed to identify the interfaces between the pilasters (i.e. lesenae), the semicolumns and the central nucleus of the pillar as well as to detect possible cracks and discontinuities inside the pillar.

3. Cathedral of Tricarico: Detection of cracks in masonry pillars by GPR and seismic tomography

The Cathedral of Tricarico is a remarkable religious architecture dating back to the 16-18th century, built on the pre-existing foundations of a previous church of the 12th century, in Basilicata.

A wide and complex phenomenon of structural instability, affecting the pillars of the central nave made necessary a multidisciplinary diagnostic campaign, including historical research and photogrammetric and direct inspections, with the aim to provide useful information for the restoration.

The investigations allowed to note a detachment of the external pilasters from the central core of the pillars of the cathedral. The pillars are shown in fig. 2 (upper and medium-left), in particular, the area without plaster was prospected with a Ris Hi Mode GPR along vertical B-scans. Some of the results of the GPR prospecting are shown in fig. 2 lower, where the results of a microwave tomography is shown. From fig. 2, we can appreciate that the external pillars do not constitute a homogeneous body together with the internal core. And some central anomalies in the central part of the bottom appear: these ones have been interpreted as fractures, probably due to some over-compression.

In fig. 2 (lower), a sonic tomography performed at 55 KHz is shown. The image refers to a horizontal section of one of the pillars. It can be appreciated that the sonic tomography indicated very well that a consistent part of the pillar probably is damaged by internal fracturations, because the velocity of the acoustic waves are consistently lower and quite more variable in the green-blue part of the achieved image with respect to the red one. The coring fully confirmed this interpretation.


In the chapel of the Holy Spirit, a Renaissance monument of the 16th century, with some subsequent baroque re-decorations, located in Lecce, we have performed an investigation for the entire floor plus the niches of the lateral walls. The main results can be resumed with the aid of fig. 3, where the results of a GPR prospecting (making use of a Hi-Mod system, manufactured by IDS, equipped with a double antenna with nominal central frequencies 200 and 600 MHz, respectively ) have been inserted into a virtual reconstruction of the monument achieved by a laser scanner survey. In particular, the anomalies C and D buried under the floor (marked with two dashed ellipses) are interpreted as a mass grave and as residual of works performed at the end of the 19th century, respectively, whereas the anomaly on niche n. 8 (marked with a dashed rectangle) is interpreted as a walled ciborium. It is available a virtual navigation within the monument, comprising also the part virtually excavated under the floor Heritage (http://www.itlab.ibam.cnr.it/QTVR.html).
Fig. 2 – Cathedral of Tricarico. Upper: longitudinal section of the church. Medium, left: Photogrammetric survey of pilasters B and D, with masonry ashlars and cracks, and an horizontal section of the pillar, where the direction (A-C) of three georadar scans are indicated. Right: Geometry of acquisition for the seismic tomographies on the pillars and velocity distribution of the P waves at height 1.03 mt and 1.47 mt. Lower: Microwave tomography (direction B-D). The rectangles indicate anomalies related to cracks of the pilaster in agreement with the surveyed cracks.
5. Discussion and conclusions
In this paper, we have shown how geophysical prospecting in historical building can give a contribution for understanding the history of the monument, its internal structure, its possible damaging problem (which is particularly relevant in the case that restoration works are scheduled). If inserted and suitably integrated with virtual and augmented reality reconstructions, the geophysical prospecting (more in general non-invasive and even slightly invasive testing) can make visible the invisible parts of the monuments and can enhance the possibilities of a remote visit with regard to the study, the enjoyment, the memory and the publicity of that particular monument.

References