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The survey and representation for the safeguard of the cultural heritage in case of emergency

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Abstract - In this short article we aim to describe the strategy and technique used to survey the Church of Sant'Andrea in Campi di Norcia, which was severely damaged by the 2016 earthquake. The church stands at the entrance of the village, in a position of relevant importance for the landscape of the Val Castoriana, on which the village overlooks. Therefore, considering the framework of damage suffered by the building and its position with respect to the access system of the village, the main objective was to secure the space surrounding the building, aiming to counteract movements of the decks and strengthen the damaged elements, to prevent further collapses. After the securing of the building, it was possible to proceed with the survey campaign. We describe the difficulties encountered due to the presence of rubble and the elements to secure the building, stressing that the survey of cultural heritage, especially in the field of property destroyed by the earthquake, is one of the most representative scenarios in which to use and test modern detection techniques. In fact, recent digital technologies offer the possibility of obtaining new products not only from the survey activities but also in the fields of representation and visualization, with the aim of having an accurate description of the territory, cities and buildings.

Keywords - Surveying, seismic injury, laser technology, enhancement, cultural heritage, representation

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The parish complex of Sant'Andrea

In the list of immovable cultural assets affected by the interventions of safety and recovery of stone material and wall paintings, appears the Church of Sant'Andrea (Group of work INGV,2016), located in the hamlet of Norcia called Campi. The church, seriously damaged following the 2016 earthquake, stands at the entrance of the village, in a position of relevant importance for the landscape of the Val Castoriana, on which the village overlooks. Therefore, considering the framework of damage suffered by the building and its position with respect to the access system of the village, the main objective was to secure the space surrounding the building, aiming to counteract movements of the decks and strengthen the damaged elements, to prevent further collapses.

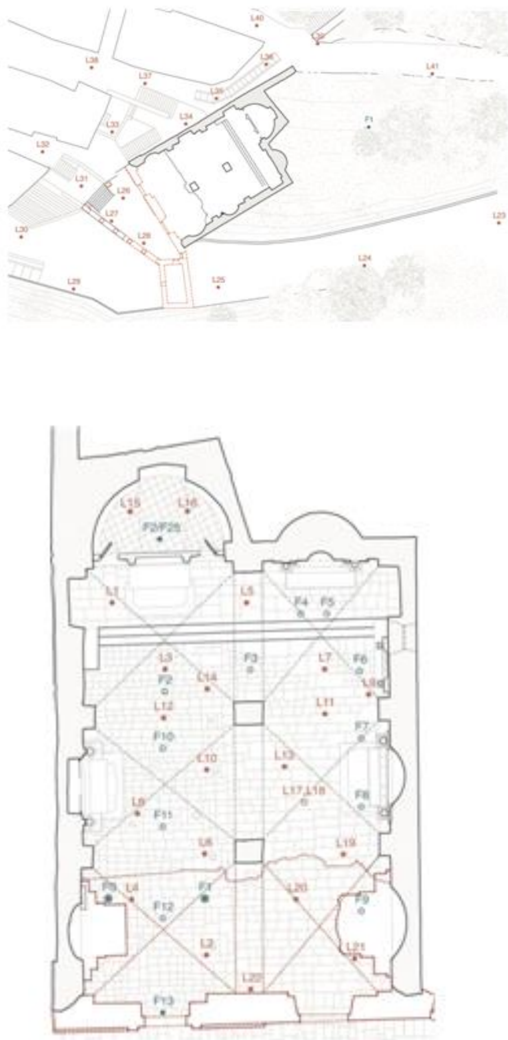
The securing of the church and its bell tower, heavily damaged by the earthquake, lasted about 20 days, during which various types of provisional works were carried out according to the design of the Fire Brigade engineer Angelo S. Capolongo and the engineer A. Borri. Once the safety operations were concluded, the Fire Brigade of Friuli Venezia Giulia, coordinated by the inspector Maurizio Malatesta of Terni, took care of the recovery of the four bells which, thanks to a mechanical arm, were lifted and brought to the ground, without creating further dangers for the stability of the church. The bells and the works of historical and artistic value have been transferred to the deposit of Spoleto while sacred vestments and liturgical objects have been delivered to the local Pro loco.

The survey campaign under emergency conditions

The use of laser technology in the architectural survey in emergency conditions is of particular interest. Interrogating the point clouds, properly calibrated and parameterized, it is possible to visualize those informations that are difficult to observe with traditional instruments and it is possible to highlight elements of particular criticality. In fact, construction anomalies, discontinuities and structural modifications become clearly legible and useful to understand the masonry factory in its complexity. In addition, the 3D laser scanner is particularly useful because it allows to detect parts of the building not reachable with traditional methods and minimizes the exposure of the operator in a high-risk context such as the survey of a building hit by an earthquake (Ferrigni, 2017). The information obtained from a survey acquired with this instrumentation is certainly more complex than a traditional survey, but it is essential to understand deformations and instabilities of the structure, elements difficult to read in the field with conventional measuring instruments. The difficulty of a survey in such conditions is twofold and depends on the complexity of the cracks and the impossibility to physically reach a certain point for the measurement.

The equipment

Laser scanners are instruments capable of measuring at very high speed the position of hundreds of thousands of points, which define the surface of surrounding objects. What you get from this type of survey is a set of points, more or less dense, commonly called "point cloud". The laser scanner can be defined as a direct measuring instrument, as it allows to obtain measurements correlated to an instrumental precision testified by a calibration certificate, which officially documents the results of the measurement. Before starting the scans, the operator is called to set some useful parameters for the definition and evaluation of the characteristics of a laser instrumentation: range, speed and step of the rotations are just some of the parameters that can be set and that determine the resolution of the scan, that is the density of the grid of points detected at a certain distance and the quality of the acquired data, typically higher for slower rotations. Since the setting of these parameters greatly affects the duration of the scan, which varies from a few seconds to several tens of minutes, it is necessary to establish upstream what level of resolution you want to obtain, to avoid wasting time and staying too long in areas of high risk. During the acquisition the instrument stores, for each point detected, the calculated distance and the horizontal and vertical angles according to the position of the body and the mirror; in addition to this information is also acquired the value of reflectivity of the surface hit by the laser: this value will be higher the more the surface will tend to white. There are also 3D laser scanners with an integrated digital camera which, after the geometric data acquisition phase, is automatically used to acquire images of the detected space. The acquired photos will be subsequently mosaicked by data processing software and applied to point clouds to enrich them with color information.



Keyplan of the scans performed with Leica P40 and Faro X330 laserscanners

The methodology

Although automatic data acquisition has been discussed above, surveying in earthquake-affected areas has some specific characteristics that make it difficult to ascribe to conventional schemes and standardized methodologies. At the time of the survey campaign (November 2017), the Church of Sant'Andrea had already been subject to safety interventions on both the external fronts and the internal aisles of the church. In particular, the interior securing proved to be particularly intrusive and made it difficult to even move around inside the hall. For this reason, it was essential to carry out a preliminary design of the survey and an inspection in order to verify the geometric characteristics of the building and the agility of all its parts.

Then, it was necessary to establish the position of the survey stations to avoid the so-called "shadow cones", areas without points due to the projection of protruding or recessed parts on the surrounding surfaces, and to set the scans to be made. The 360° scans with an average density of points were flanked by very high-density scans for smaller areas that were particularly difficult to reach or with more complex geometries. These scans were carried out with two different scanners: the Leica P40, used for the 360° scans both inside and outside, and the Faro X330, lighter and more manageable, useful for the scans inside the bell tower and for those to be set at levels raised above the floor.

Since a large number of scans were necessary to acquire all the surfaces, the survey phase was followed by a post-processing phase, during which the various scans were assembled together on the basis of the points they had in common, through the use of specific software. At the end of this phase the model could be considered complete and we moved on to the cleaning of the cloud of points, eliminating any errors, portions of the survey not interesting and securing. At the end of this process the point cloud has become the fundamental and essential tool for the architectural survey and for all the design evaluations that followed.

The role of photography

The laser scanner survey was accompanied by a photographic survey campaign. Although the laser scanner used was able to obtain photographic data from the scans made, often, due to poor lighting conditions, the data obtained was not usable. The photographic campaign, therefore, constituted a

fundamental support to the survey, allowing to obtain, in addition to the geometric data, also the tonal data of the rich decorations of the altars and proved to be an indispensable component in the survey of the deterioration of the internal surfaces.

Church of Sant'Andrea in Campi di Norcia; the presence of rubble and securing made laser scanner survey operations difficult.

Difficulties experienced

The survey campaign was carried out taking into account the considerable difficulties of the site. The presence of rubble made some scans largely incomplete, especially near the collapsed span. Moreover, the securing of metal structures inside the building made the movements of the operators difficult and increased the number of stations necessary for a complete restitution. The same securing has also made necessary a long cleaning phase of the scans, in order to eliminate these structures. The reading of the "cleaned" model results however of difficult readability.

The interpretation of damage

It was decided to postpone the data processing phase to reduce the risk deriving from the exposure of the operator in unsafe places such as those of the church hit by the earthquake: the automatic acquisition of a large quantity of data allowed to shorten exponentially the time spent there. The graphical elaborations obtained are easily understandable and accurately communicate the metric data also making use of a strong graphic impact, but this obligatory division of work into two successive phases, one of campaign and one of elaboration, can lead to many interpretative problems. In fact, lacking the direct contact with the factory during the elaboration of the data, misunderstandings can be generated in the reading of the detected data. The reading of the failure mechanisms of the factories is particularly easy for what are defined as first-mode damages, that is activated by forces acting orthogonally to the facade plane and therefore generating off-plane damages such as rotations, overturnings or material ejections. As far as the second mode damages are concerned, the reading is not so easy: these damages, caused by forces acting in the masonry plane, generate above all shear cracks in the masonry males and in the plane bands. This type of damage is testified by the typical breaks of the masonry to X and just because it happens in the same plan of the masonry is not directly legible as displacements of the masonry material in comparison to a zero. (Beolchini, 2013)

For this reason, this type of graphic elaboration should always be accompanied by drawings and traditional analyses, such as crack or deformation pictures, to make a more complete reading at a later time. Only in this way is it possible to obtain a global view of a complex system such as that of this building, in order to have adequate information about the state of health of the same after the earthquake. In fact, other aspects must always be considered, such as the state of conservation and degradation of the material that makes up the masonry and the quality of the connections between the parts of the building. (Bitelli, 2012)

From point cloud to 3D restitution

The first step of the process is cleaning, i.e. removing noise points and anything else that you do not want to be part of the model. This process was also applied to the church of Sant'Andrea, improving and cleaning the data acquired after registration by removing superfluous data such as snow or rubble. The second phase is the two-dimensional representation in which we proceed with the realization of the vertical and horizontal cutting planes (slice), creating thin "slices" of the model from which to extrapolate plans and vector sections (Paoletti, 2011). Given the complexity of the building, disposed on more levels, with the internal safety and the precarious conditions of the structures, the elaboration process has been particularly long and demanding. The third phase includes all the indirect aspects of the survey, the two-dimensional raster representation, or the internal and external photoplans. These aspects are extremely important for the analysis and for an understanding of materiality and architectural degradation. The techniques to create the photoplans are varied, modern lasers in addition to making an accurate spatial survey, obtain the photographic data by creating a texture applied to the point cloud, however, in the case under consideration, due to the shadow cones caused by the structures of the safety, it was not possible to perform these operations automatically. The process illustrated so far is aimed at the graphic restitution of the situation for a correct analysis of the building under examination. The last step to effectively represent the factory is the realization of an orbitable 3D model (Girelli, 2007).

View of the town of Campi di Norcia. The elaborate has been obtained from the union of the scans made with the Leica P40 laser scanner

The survey of cultural heritage and the valorization of the data obtained

The survey of cultural heritage, especially in the field of the goods destroyed by the earthquake, is one of the most representative scenarios in which to use and test modern surveying techniques (Raniolo, 2018). In fact, the recent digital technologies offer the possibility to obtain new products not only from the survey activities but also in the fields of representation and visualization, with the aim of having an accurate description of the territory, cities and buildings. It is therefore evident how these new technologies can be fundamental in the specific field of conservation and restoration. (Bellini, 2014)

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