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Three-dimensional imaging from non-destructive techniques in the characterization of stone building materials

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The acquisition of 3D data by means of different methodologies on architectural monumental structures when combined can highlight with efficiency the characteristics of the stone building materials. The result is a three-dimensional imaging of different physical properties that can be analyzed and interpreted more objectively and accurately than the conventional two-dimensional ones.
We have applied various three-dimensional non-destructive techniques to produce data that can better visualize and detect defects in the shallow and inner parts of the architectural elements built with stone materials. The 3D data volume of a different nature provides a less ambiguous image of the materials and contributes in efficiency by increasing both fidelity and resolution in the diagnostic process.
In this paper, we combined high resolution Digital Color Images (DCI) and Terrestrial Laser Scanner (TLS) data for a dense 3D reconstruction of an ancient pillar in a monument of the town of Cagliari, Italy. The TLS technique was supported by a digital photogrammetry survey in order to obtain a natural color texturized 3D model of the study pillar. The 3D model was built with a specific software aligning and combining a set of 2D high resolution color images captured all around the investigated architectural element from multiple viewpoints using a normal handheld 2D digital reflex camera. Final high resolution natural color 3D model reproduces a faithful metrically –correct-scale copy of the analyzed structure and therefore can be effectively compared with the surface geometric anomalies and reflectivity values obtained by the TLS. During the TLS survey we operated a Leica HDS-6200 long-range phase shift terrestrial laser scanner in order to compute an aggregated 3D cloud representing the pillar surface texturized with its reflectivity and the position of the pixels in an intrinsic reference system. Geometrical anomaly maps showing interesting analogies were computed either from the 3D model derived from the TLS application or from the high resolution 3D model detected with the photogrammetry. Starting from the 3D reconstruction from previous techniques an acoustic tomography in an sector of prior interest of the investigated architectural element was carried out. Travel time of longitudinal elastic waves were measured along a great number of measurement paths between stations located on the perimeter of the investigated sections. Each station was alternatively used as transmitter and receiver and measurements of paths crossing the section in a large number of different directions were carried out. Each ray between stations divided in small segments, each corresponding to a pixel element. Inversion techniques were used to obtain a map of the distribution of the longitudinal wave velocity across the sections, thanks to specific software exploiting appropriate reconstruction algorithms. The ultrasonic tomography proved to be an effective tool for detecting internal decay or defects, locating the position of the anomalies and estimating their sizes, shapes, and characteristics in terms of elastic-mechanical properties. Finally, the combination of geophysical and petrographical data sets represents a powerful method for understanding the quality of the building stone materials in the shallow and inner part of the investigated architectural structures.