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Non-Destructive, Non-Contact Conservation Techniques Applied to Historic Structures Combining Terrestrial Laser Scanning and Infrared Thermography

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In order to preserve the integrity of historical buildings, non-destructive, non-contact techniques for conservation should be implemented where and when possible.

I'm going to speak about two of these techniques, presenting case studies using both methods:

- 3D Terrestrial Laser Scanning (TLS)
- Infrared Thermography (IRT)

3D Laser Scanning

- 3D Data Set = Point Cloud
- Colors in the scan data represent intensity of reflection from the surface
- Intensity backscatter = nominal value assigned to each and every laser that fires and returns back to the scanner. If the geometry of a subject is irregular and absorbs or refracts light in a way that differs from the other subjects being scanned, we can normalize that reflective (intensity) value to a color.
- Real-time, geometric measurement.
- Detect residuals on the building.
- Defines a reference for the monitoring of structural modification and damages.

Thermal Imaging /Infrared Thermography (IRT)

- Based on the measurement of the heat energy and its conversion into an electrical signal, which is represented by thermal digital images (measurement of surface temperature).
- Thermographic data can identify anomalies before they cause further damage.
- Cost effective thermal cameras.
- 2D data acquisition

By combining and fusing the data collected from laser scanning and thermography, a comprehensive mapping and monitoring of damages of façade systems is possible for:

- Building Façade Maintenance
- Building Efficiency
- Building Conservation
- Building Assessment Before/After Disaster

Building Façade Maintenance

Administrative Bulletin AB-110 signed by San Francisco Department Building Inspection Director Tom Hui to establish policies for implementing San Francisco Existing Building Code Chapter 4E regarding building façade inspection and maintenance.

Inspection Procedures

E. Remote sensing techniques, including 3-D survey may be proposed by the qualified professional . . .

Inspection of Historic Resources

2. Inspection methods for historic resources shall use the least intrusive or invasive means feasible to effectively assess hidden conditions.

Building Efficiency

The ability to visualize heat makes thermography a powerful tool for studying energy efficiency. Excessive levels of heat loss through a structure are easily located with further investigation required to determine the cause (e.g. poor insulation, air leakage, etc.).

Building Assessment after Disaster

Case Studies – Application of 3D Technologies After South Napa Earthquake

Case 1. – Gordon Building (National Register) / Scan Data Analysis Before and After the Earthquake

The resulting evaluation was used to assess failure of the structure and to what extent the damaged posed a safety hazard. Published article in LiDAR News, titled "3D Laser Scanning Technology – Key in Preserving Historic Structures After South Napa Earthquake".

Case 2. – Center Building (Local Landmark) / Deconstruction of the Historic Stone Façade

This building suffered extensive structural damage with the front brick and stone façade separating from the frame of the building. A scan to CAD solution saved the building at risk for demolition.

Case 3. – Goodman Library (National Register) / Laser Scanning Solution for Structurally Unsound Roof Top

Laser scanning is an effective, non-invasive method to capture buildings too fragile or structurally unsound for direct contact. The scan data was used to accurately measure the tower virtually, which enabled the architects and engineers to design the containment structure without physical contact to the building or roof top.

Building Conservation

Case Study – St. Augustine Monumental Compound, located in the historical center of the town of Coscenza in Southern Italy. The monastery was built in 1507 and suffered extensive damage from earthquakes, fire and subsequent seismic events.

Overlaying and comparing the collected data using a combination of 3D Laser Scanning for 3D reconstruction and Infrared Thermography to detect the thermal anomalies aimed to realize a monitoring system of monumental buildings in seismic areas and to analyze the vulnerability of the structural elements.

TLS was used to define an accurate geometry of the building, necessary to assess the correct spatial position and the geometric dimension of all structural elements (Image 1. = Point Cloud). Some architectural elements were meshed for a more realistic representation (Image 2. = Mesh).

For more detailed analysis, some elements were scanned at a higher resolution. In order to verify any anomalies, the external façade was investigated, comparing the information detectable from (Image 3) the 3D mesh (a); thermal image (b); intensity of reflection from the surface (c).

- Cracks barely visible to the naked eye become easily detectable from both the 3D scan and thermographic image (a)
- Imperfections, like swelling or detached plaster are identified and seen as color variations on the thermographic images and reflectance map (b)(c).
- Residuals show large irregularities where originally a rosette had been realized as reported by the historical survey (c).
- (Image_4). An arch shape is observed indicated by a change in temperature. It can be hypothesized to be a hidden arch; possibly another original element (a). Different observations are made from a comparison on images taken in the morning and evening (a)(b).

An analysis of the residuals of the external wall was performed (Image_5). In the central part of the wall, the presence of significant positive out of plane deviations were detected. These problems are probably due to ground settlement and are related to the configuration of the structure and its transformations over time.

The relevant negative deviation in the upper part of the wall is a behavior conditioned by the presence of tension rods put in place to reduce the tilting of the masonry.

The temperature analysis of the thermographic survey (Image_6) demonstrates high local differences in the masonry.

The wall was constructed by stones covered by plaster, while the buttresses are made of composite material containing both stones and bricks, perhaps built in a subsequent period respective to the wall.

The condition of the wall is important for the evaluation of the mechanical strength to be assigned to the masonry.

The presence of moisture is detected at the lower part of the wall due to the capillary rise of water from the subsoil.

(Image_7)(a) One of the most damaged columns was scanned at a higher resolution shows cracks and a variable degradation of the stone material.

(Image_7)(b) The blue areas of the residual map shows the more degraded zones of the stone blocks (blue areas).

Conclusion:

Combining both technologies improved the knowledge of the conservation state of the historic building.

The conceived methodology can be useful for the assessment of the health status of historic buildings for purposes relating to conservation and restoration activities.

Short time required for the data acquisition; High potential of analysis and significant results suggest the adoption of this survey methodology in a protocol for the preservation of the architectural and cultural heritage against calamities.

This strategy could allow the observation of the progression of decay over time, confirming the possibility of monitoring the effects on ancient buildings due to natural disasters, such as earthquakes.