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To cite this version:

HAL Id: hal-01883674
https://hal.science/hal-01883674
Submitted on 28 Sep 2018

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Ultrasonic imaging of antique statue combining laser vibrometry and photogrammetry

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The framework of the conservation of cultural heritage, non-destructive inspection methods are of interest, especially ultrasonic investigation which is the only method with a direct and physical relationship with the mechanical state of the medium. The ultrasonic measurements are usually performed with a transmitter and a receiver applied on opposite positions at the surface of the artwork to measure the time of flight from whom the ultrasonic velocity will be deduced. This traditional device presents two main limits: drawbacks:

1) The geometrical model is built using 3D photogrammetry

2) Ultrasonic signals acquisition is performed using a red He-Ne scanning laser vibrometer (632.8nm) monitored by a camera.

3) The ultrasonic image is built combining the geometrical model and ultrasonic signal processing. The distances d are deduced from the geometric model to calculate the velocity (V=d/t) and the attenuation (A=A0e-αt). The absolute amplitude measure provided by the laser is employed to reconstruct both velocity and attenuation maps.

The test results show that using laser vibrometry and photogrammetry offer the possibility to image both the marble homogeneity in the bulk of the statue as well as crack profiles at its surface (perspective: to use a second laser as transmitter to have a full no contact configuration).

Test piece

Site museum of Alba la Romaine

This method is applied on a Roman marble statue of the site museum of Alba-la-Romaine (Musée, Ardèche, France). In the frame of a multidisciplinary study, a global ultrasonic auscultation was made in order to assess the mechanical diagnosis and to design a safe, reversible and non invasive base for this artwork [1]. The result shown that the marbre was very homogeneous and in good condition with an average ultrasonic velocity of 4200m/s.

Nevertheless an in-depth auscultation was needed on several worrying millimetric cracks noticed in the left groin and close to the left arm. It was decided to test a scanning laser beam as receiver to make some ultrasonic mappings and evaluate the depth and opening of the cracks as well as the homogeneity of the marble within the artwork.

Methodology

3 steps
1) The geometrical model is built using 3D photogrammetry

500 photos (Nikon D800E – 36x24pixs, 2 focal lengths 24 and 50mm).

The MicMac photogrammetric open-source suite of tools is used to generate the point cloud.

Photographic acquisition (stereom of the museum)

Points cloud

2) Ultrasonic signals acquisition is performed using a red He-Ne scanning laser vibrometer (632.8nm) monitored by a camera.

Points cloud

3) The ultrasonic image is built combining the geometrical model and ultrasonic signal processing.

Application test on the statue

a) Auscultation of crack

Experimental device

Use of the geometric model

Crack depth ≤ 31mm

Time Of Flight map

Crack profile is closed, may be due to self healing over time.

The test results show that using laser vibrometry and photogrammetry offer the possibility to image both the marble homogeneity in the bulk of the statue as well as crack profiles at its surface (perspective: to use a second laser as transmitter to have a full no contact configuration).

Acknowledgements: The authors wish to thank Aude Poinsot, head of MuséAl (site museum and archaeological site of Alba-la-Romaine) for her support. They are also grateful to Emmanuel Debroeche, freelance restorer, and Emmanuel Mylle, technician of MuséAl, for handling the statue.