

Ultrasound-based multimodal imaging for cultural heritage: transdisciplinary studies for evaluating the aging of the weathered Tuffeau stones

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There is a pressing need in the domain of cultural heritage (CH) to increase the information stored in digital images coming from the Nondestructive Testing (NDT) inspection of ancient stones, and to make this information accessible to computers and humans[1]. The main objective of NDT for CH is to make multi-, inter- and trans-disciplinarity be the keywords of modern aging evaluation of complex assets in the CH domain. The specific challenge of NDT4.0 associate to CH is to increase the volume and the level of digital images coming from novel multi-modal/multi-physics combinations of NDT techniques of ancient stones (e.g. Ultrasound and THz-imaging). It is necessary to promote multi-scale and multi-modal image processing, analyze and annotate these NDT data and images, and will publish the new hi-tech content through the existing CH databases. In order to conduct this goal, the interaction between an acoustic wave and a complex media has an increase interest for both aging applications in NDT and for biomedical ultrasound[2]. Today, new optimized excitations are generated thanks to the analysis of symmetry properties of the system such as reciprocity, nonlinear time reversal (TR) and other pulse-inverted (PI) techniques. Generalized TR based NEWS (Nonlinear Elastic Wave Spectroscopy) methods and their associate symmetry skeleton will be taken as an example. As another application of mixing properties in a wide frequency range, new broadband techniques are needed in the domain of the preservation of cultural heritage. The analysis of the composition of the stones is one of the key parameters in the study of aging historic buildings. The use of TR-NEWS based analysis combined with a FTIR-based system has shown a specific property of the tuffeau limestone where damaged sample contains calcite. In both domains, ageing properties of complex medium are extracted thanks to the use of enhanced nonlinear signal processing tools. It is shown that the symbiosis of ultrasound-based multimodal imaging and terahertz methods can provide an important diagnostic tool for cultural heritage applications. Chemical analysis is also necessary, for example, to identify the nature of the weathering and the aging. REFERENCES : [1] Serge Dos Santos and Nathalie Poirot, Optimized analysis for nonlinear ultrasonic imaging in complex media : acoustic imaging for cultural heritage, 19th World Conference on Non-Destructive Testing (WCNDT 2016), 13-17 June 2016 in Munich, Germany (WCNDT 2016), <https://www.ndt.net/article/wcndt2016/papers/mo2b3.pdf> [2] Dos Santos, S., Lints, M., Poirot, N., & Salupere, A. Optimized excitation for nonlinear wave propagation in complex media: From biomedical acoustic imaging to nondestructive testing of cultural heritage. The Journal of the Acoustical Society of America, 138(3), 1786-1796. (2015).