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A Monte Carlo approach applied to ultrasonic non-destructive testing

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Non-destructive testing based on ultrasound allows us to detect, characterize and size discrete flaws in geotechnical and architectural structures and materials. This information is needed to determine whether such flaws can be tolerated in future service. In typical ultrasonic experiments, only the first-arriving P-wave is interpreted, and the remainder of the recorded waveform is neglected. Our work aims at understanding surface waves, which are strong signals in the later wave train, with the ultimate goal of full waveform tomography. At present, even the structural estimation of layered media is still challenging because material properties of the samples can vary widely, and good initial models for inversion do not often exist.

The aim of the present study is to combine non-destructive testing with a theoretical data analysis and hence to contribute to conservation strategies of archaeological and architectural structures. We analyze ultrasonic waveforms measured at the surface of a variety of samples, and define the behaviour of surface waves in structures of increasing complexity. The tremendous potential of ultrasonic surface waves becomes an advantage only if numerical forward modelling tools are available to describe the waveforms accurately. We compute synthetic full seismograms as well as group and phase velocities for the data. We invert them for the elastic properties of the sample via a global search of the parameter space, using the Neighbourhood Algorithm. Such a Monte Carlo approach allows us to perform a complete uncertainty and resolution analysis, but the computational cost is high and increases quickly with the number of model parameters. Therefore it is practical only for defining the seismic properties of media with a limited number of degrees of freedom, such as layered structures.

We have applied this approach to both synthetic layered structures and real samples. The former contributed to benchmark the propagation of ultrasonic surface waves in typical materials tested with a non-destructive technique (e.g., marble, unweathered and weathered concrete and natural stone).