Efficient computation of acoustic sensing by means of *hp*-adaptive finite elements

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ABSTRACT

Sensing by means of acoustic signals excited into a probed medium is of great importance for the non-invasive inspection in geophysical and biomedical applications, as well as in the non-destructive characterization of complex materials in aeronautical, mechanical and civil engineering. To deduce the spatial distribution of material properties of the probed medium from acoustic measurements requires the solution of an inverse problem. The numerical solution of problems arising from acoustic sensing poses great challenges for computational wave-propagation techniques. The truncation of the typically unbounded physical domain to a finite computational domain requires a special treatment of the truncated boundaries to avoid non-physical reflections. The *Perfectly Matched Layer* (PML) is commonly used to enable such reflectionless truncation. However, the PML property of being reflectionless holds only on the continuum level; under discretization, this property is compromised and spurious reflections typically do occur. Further computational challenges pertain to the efficient tracking of propagating waves and the accurate resolution of material interfaces in the probed medium. Stringent accuracy requirements render customary approaches based on uniform or even manually refined discretizations often prohibitive.

In our talk, we consider acoustic sensing in a borehole environment, which is routinely used in exploratory geophysics, and we show that an adaptive discretization with automatic refinement is ideally suited to meet the above mentioned challenges. In contrast to conventional discretizations, we have developed an hp-adaptive finite-element discretization [1] that enables us to adjust the element size h and the polynomial approximation order p to the local resolution requirements of the solution. The adaptivity is carried out automatically, i.e. no interaction with the user is required. Such adaptive refinements automatically minimize the discretization error and resulting reflections from the PML to a user-specified accuracy, thus avoiding tedious PML parameter tuning [2]. Moreover, propagating wave fronts and material discontinuities are automatically detected by our algorithm and the discretization is adjusted accordingly to optimize computational efficiency.

We demonstrate the improvements offered by our adaptive algorithm through numerical results for the acoustic probing of subsurface rock formations penetrated by a fluid-filled borehole. The numerical results show that automatic adaptivity allows us to efficiently compute the time and space response of acoustic wave propagation excited into the probed medium to a user-specified accuracy.

REFERENCES

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