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IMAGING OF COMPLEX MEDIA WITH ELASTIC WAVE EQUATIONS

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Since a large number of sedimentary basins have been explored, oil exploration is now interested in investigating regions of the Earth which are hostile. Reliable techniques of subsurface imaging are thus welcome by oil industry because they may provide an efficient tool to decide if drilling has any chance of success. Among existing methods for seismic imaging, Reverse Time Migration (RTM) is a technique known by industry to be efficient. RTM uses reflected waves and is able to construct a map of the subsurface which is depicted by the interfaces limiting the geophysical layers. But since RTM involves many solutions of full wave equations, it is computationnally intensive and it is still difficult to image realistic 3D elastic media, even with the help of High Performance Computing. RTM is initialized by producing a smooth map of the Earth. It usually results from the interpretation of recordings obtained during an acquisition campaign. RTM can then be described as a three-step procedure: **(i)** compute the wavefields emitted by the sources used during the seismic acquisition campaign; **(ii)** for each source, compute the so-called "backpropagated wavefield", which is the wavefield obtained by using as sources the signals recorded at the receivers during the acquisition campaign and by reversing the time; **(iii)** get an image of the subsurface by applying an imaging condition combining the propagated and the backpropagated wavefields at each time step of the numerical scheme and for each source.

Even if RTM has enjoyed the tremendous progresses of scientific computing, its performances can still be improved, in particular when applied to strong heterogeneous media. In this case, images have been mainly obtained by using direct arrivals of acoustic waves and the transition to elastic waves including multiples is not obvious essentially because elastic waves equations are still more computationnaly consuming. The accuracy of numerical wave fields is obviously of great importance. We have thus chosen to consider high-order Discontinuous Galerkin Methods which are known to be well-adapted to provide accurate solutions based upon parallel computing. Now one of the main drawback of RTM is the need of storing a huge quantity of information which is redhibitory when using elastic waves. However RTM procedure can be modified by giving up the idea of applying steps (i)-(iii) sequentially. For that purpose, we apply the Griewank algorithm [2] following Symes' ideas [3] for the acoustic RTM. The idea is to find a compromise between the number of wave equations to solve and the number of numerical waves that we have to store. This is the so-called Optimal Checkpointing. By reducing the occupancy of the memory, RTM should be efficient even when using elastic waves. By this way, the question of knowing if considering elastic waves including multiples allow to improve images of heterogeneous media could be considered. It must involved a careful numerical analysis including the evaluation of the impact of the imaging condition. It is thus necessary to derive accurate imaging conditions, which could take advantage of all the information contained in the wavefield. For acoustic media, Claerbout [1] proposed an imaging condition which is widely used and turns out to be sufficient to accurately reproduce interfaces. But Claerbout conditions do not take wave conversions into account and it is not clear if conversions do or do not not contain interesting information to get accurate images of heterogeneous media. However, since P-wave and S-wave interact with each other, it might be relevant to use an imaging condition including these interactions. In fact, this has been done successfully by J. Tromp and C. Morency [6] for seismology applications based upon the inversion of the global Earth. Their approach is based upon the state adjoint and it involves sensitivity kernels which are defined from the propagated and the backpropagated fields. Now it has been shown in [5] that full wave form inversions using these sensitivity kernels may be polluted by numerical artefacts. One solution is to use a linear combination of the sensitivity kernels to delete artefacts. In this work, we propose then a new imaging condition which construction is inspired from [5] with some approximations required to keep admissible computational costs. We illustrate the properties of the new imaging condition on industrial benchmarks like the Marmousi model. In particular, we compare the new imaging condition with other imaging conditions by using as criteria the quality of the image and the computational costs required by the RTM.

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