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Full Waveform Inversion: Past, Present and Future

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Summary

Seismic reflection data are acquired at a very high cost. Conventional processing (stacking and migration) provides very high-quality image of the sub-surface, but does not provide any quantitative measure of the physical properties of the sub-surface. Amplitude versus offset (AVO) analyses can be used to estimate P and S-wave impedances. Since the method is local, i.e. assumes 1D media, linear approximation to the reflection coefficient, and ignores interference effects, the results are very approximative.

In 1980s Tanantola's group in Paris started developing full waveform, while other groups were focusing on different types of migration algorithm using more sophisticated mathematical techniques. Tarantola shows that first iteration of full waveform is equivalent to migration, and as iteration proceeds, one starts taking non-linearity into account and start modeling the physics of earth propagation. The main problem with Tarantola's approach was that he was focusing only on inversion of near offset, which has limited sensitivity for intermediate wavelength of velocity. In early 1990s our group started working on full waveform inversion (Singh et al, 1993) but used long offset data to get medium to large-scale velocity of the sub-surface. We showed that wide-angle reflection data (Neves and Singh, 1996) has sensitive to intermediate wavelength information. Joint inversion of near- and post-critical angle reflections data allowed convergence towards the global minimum (Shipp and Singh, 2002). Since then we have extended the algorithm to multi-component OBC data to invert P and S-wave velocity (Sears et al., 2008; Roberts et al., 2008) and attenuation. Although, our group has made significant progress, computation remains a main issue in applying elastic full waveform inversion on a routine basis.

In late 90s, the group at Imperial College led by Pratt started developing waveform inversion in the frequency domain. Pratt suggested that by using single discrete frequency one can reduce the computation cost significantly. One can start with low frequencies and then successively invert the frequency data. This was a very attractive option but had certain limitation. First, one would require very wide-aperture data (long offset) in order to reduce the effect of single frequency ringing. Secondly, the method is very memory hungry, which meant that it was mainly applicable to 2D acoustic case, but the acoustic approximation is not valid for wide-angle reflection data. Therefore, the method has been mainly used to first arrival refraction data.

In this talk, I will give a historical prospective of the full waveform inversion, the present state of the art techniques in full waveform and then propose a strategy for future waveform inversion. We are presently taking full waveform a step further by jointly inverting both seismic and controlled source electromagnetic data.

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