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Estimating Primaries from Passive Seismic Data Using Noise Sources

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SUMMARY

Passive sources usually include two types: transient and noise sources. The paper estimates primaries from the passive seismic data which passive sources are the noise ones. When the traditional method of estimating primaries by sparse inversion from passive seismic data using transient sources is not useful, we propose to solve the inversion problem by the least-square algorithm based on the minimum energy principle and test on a 2D synthetic data. It proves that the method is effective and accurate.

Introduction

In passive seismic exploration, passive sources like transient ones or noise ones are used, such as the natural earthquakes, background noise and so on. The virtual-shot gathers obtained by cross-correlation not only contain the primaries, but also include the surface-related multiples. In 2010, Van Groenestijn and Verschuur proposed estimating primaries by sparse inversion from the passive seismic data under the assumption that the data is sparse. With this method, the primary reflection coefficients can be obtained directly from the passive seismic data. But it realizes under the condition which the passive sources are transient ones. When the passive sources are the noise ones, the assumption that the data is sparse is not satisfied.

The paper estimates the primary reflection coefficients from the passive seismic data which passive sources are the noise ones. Since the noise data is not sparse, the traditional method of estimating the primaries by sparse inversion cannot be used. In this case, we use the least-square algorithm to estimate the primaries from the noise data.

Estimating primaries from the noise data

Van Groenestijn and Verschuur(2010) introduce EPSI to process the passive seismic data. The big difference between the control-source seismic data and the passive seismic data is that there is no primary reflection responses in the passive seismic data, which are replaced by the direct arrivals from passive sources toward the surface. The direct arrivals cause a series of surface multiples. That expression is

$$\vec{P}_{pas}^- = \vec{P}_{dir}^- + X_0 R^\cap \vec{P}_{pas}^- \quad (1)$$

Where $\vec{P}_{pas}^-$ and $\vec{P}_{dir}^-$ represent individually the upgoing wavefield and the direct-wave wavefield, X_0 represents the reflected coefficients of primaries, $R^\cap$ is the surface-related reflected operator. It is no longer enough to solve the two unknowns $\vec{P}_{dir}^-$ and X_0 by the sparse constraint on X_0 in the time domain. Then they used an extra constraint which assumes that $\vec{P}_{dir}^-$ has minimum energy. Make the equation (1) rearranged, then

$$\vec{P}_{dir}^- = \vec{P}_{pas}^- - X_0 R^\cap \vec{P}_{pas}^- \quad (2)$$

So the objective function to minimize is

$$J_i = \sum_{\omega} \sum_{j,k} \left| \vec{P}_{pas}^- - \hat{X}_{0,i} R^\cap \vec{P}_{pas}^- \right|_{j,k}^2$$

In this paper, the passive seismic data which passive sources are the noise ones is used to estimate the primaries. We solve the inversion problem by the least-square algorithm based on the minimum energy principle.

Examples

The idea is tested on a 2D synthetic data which the model is shown in Figure 1. Noise sources are set on the bottom and receivers are set on the surface. It requires a long recording time. Figure 2 shows one part of the passive seismic data. It can be seen that any useful message cannot be obtained from the passive seismic data. The zero-offset profile of the virtual-shot gathers obtained by cross-correlation is shown in Figure 3b. It is known that the virtual-shot gathers not only contain the primaries, but also include many multiples comparing with the zero-offset profile with standard acquisition which only contain the primaries(also including the internal multiples) shown in Figure 3a.

Next, we use the method proposed above to estimate the primary reflection coefficients. Then, make the primary reflection coefficients estimated convoluted with any wavelet. The zero-offset profile estimated which direct wave has been muted is shown in Figure 3c. Comparing with the result of

cross-correlation, the surface-related multiples have been suppressed effectively in the zero-offset profile estimated. Although much noise is still present, the primaries are obvious.

Conclusions

The paper estimates primaries from the passive seismic data which passive sources are the noise ones. When the traditional method of estimating primaries by sparse inversion is not useful, we propose to solve the inversion problem by the least-square algorithm based on the minimum energy principle. The method proposed has estimated the primaries successfully from the noise data. It proves that estimating primaries from the passive data which passive sources are the noise one by solving the inversion problem by the least-square algorithm based on the minimum energy is feasible and effective.

Figure 1 The subsurface model.

Figure 2 The passive seismic records.

Figure 3 *a)* The zero-offset profile with standard acquisition which only contain the primaries and the internal multiples; *b)* The zero-offset profile obtained by cross-correlation; *c)* The zero-offset profile obtained by estimating primaries via L2-norm.

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References

Van Groenestijn, G.J.A. and Verschuur, D.J. [2010] Estimation of Primaries by Sparse Inversion from passive seismic data. *Geophysics*, **75**(4).