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Solving the Problem of Conflicting Dips in Common-Reflection-Surface (CRS) Stack

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SUMMARY

CRS stack procedure is a data-driven imaging method which is independent of an explicit velocity model. The pragmatic search strategy for CRS attributes consists of three one-parameter searches. This implementation determines only one optimum stacking operator for each ZO sample to be simulated. Consequently, conflicting dip situations are not taken into account. In one of the efforts to overcome this problem, the strategy has been extended in order to take into account up to five conflicting dips at each sample. Here, we propose a strategy which considers all possible angles and, thus, accounts for all the conflicting dips that may exist at one sample. This strategy has some advantages that improve the continuity of reflection events as well as diffractions in the presence of conflicting dip situations. It also generally emphasizes diffraction events in the stacked section such that we may call it common-diffraction-surface stack. Here, we processed the Sigsbee 2A synthetic data and a real land data set with the new method. The stacked result of Sigsbee 2A and the results of the poststack depth migration of the real data also proved that the stacked section of the CDS stack is a suitable input for migration.

Introduction

The Common-Reflection-Surface (CRS) Stack is a data-driven imaging method to simulate a zero-offset (ZO) section from seismic reflection prestack data (Hubral, 1999). Introduced by Müller (1998) as a ZO simulation method for 2D, it does not require an explicit knowledge of the macro-velocity model. For the 2D case, the shape of the operator depends on three parameters and can be considered as the approximate reflection response of a circular reflector mirror segment, the so-called CRS (Jäger 1999). Any contributions along any realization of this operator are tested by means of coherence analysis for each ZO sample. The CRS stack has the potential to sum up more coherent energy of the reflection event than conventional stacking methods which results in a high signal-to-noise ratio (S/N) in the simulated ZO section (Mann et al. 1999a). However, in each ZO section we could see that in some cases the events intersect each other. It is obvious that at samples where such situations occur, a single stacking operator associated with only one triplet of optimum attributes is not sufficient.

Pragmatic and extended search strategies

To apply CRS stack in data oriented way, its attributes have to be determined automatically from the prestack data. The most efficient solution of CRS equation

$$t^2(x_m, h) = \left(t_0 + \frac{2 \sin \alpha}{v_0} (x_m - x_0) \right)^2 + \frac{2 t_0 \cos^2 \alpha}{v_0} \left(\frac{(x_m - x_0)^2}{R_N} + \frac{h^2}{R_{NIP}} \right) \quad (1)$$

where R_{NIP} is radius of Normal-Incidence-Point wave, R_N is radius of Normal wave, and α is emergence angle of the normal ray, can be achieved by decomposing it into three separate optimization problems with a search for one parameter in each (Jäger 1999). The pragmatic search strategy can be summarized as follows: automatic CMP stack, where $x_m = x_0$, ZO stack, where $h=0$, and an optional local optimization with the full spatial operator (1). Mann (2001) introduced an extended strategy for CRS stack to overcome the problem of conflicting dip situations in this method. In the extended strategy, the automatic CMP stack is performed without considering conflicting dip situations, but its result is used to resolve the problem of conflicting dips: additional local coherence maxima are considered in the linear ZO stack and all following steps.

In this way, different numbers of maxima in the angle spectrum could be taken into account. These events are selected based on the coherence analysis performed on the CMP-stacked section. Then a set of emergence angles $\alpha^{(i)}$ and their associated normal wave radii $R_N^{(i)}$, where the index $i = 1, 2, \dots, n$, numbers the n detected events contributing to a particular ZO sample, are available. To determine the last attribute, R_{NIP} , Mann (2002) proposed to search in another subdomain of the prestack data, namely common shot (CS) and common receiver (CR) gathers. This is only a one-parameter search and provides $R_{NIP}^{(i)}$ section for each detected angle. The next step is to perform optimization and stack with the optimum surface stack.

The concept of the common diffraction surface (CDS) stack

In CRS stack method, the same idea as DMO was used to overcome the problem of conflicting dips. In this case, the reflectors in depth domain might be of arbitrary shape. The number of conflicting dips is not of interest here, because any conflict that could be present will contribute to the stack for that sample. For each sample, a coherence analysis is performed for a range of emergence angles.

CDS operator

In the ZO section, we often encounter intersections of reflection events and diffraction events. Solving the problem of conflicting dips will enhance the usually weak diffraction events in the stacked section. As the new strategy not only addresses reflection events but in particular diffraction events, it is called common-diffraction-surface (CDS) stack. By considering all

possible angles in the CRS equation, a set of operators will make a weighted volume instead of a single surface in the prestack data domain.

For actual diffraction events, the radii of NIP wavefront and normal wavefront coincide, i. e. $R_{NIP}=R_N$. Nevertheless, we can use the traveltimes approximation for a diffraction event to perform stack for reflection events as well. The only attribute to be searched for a fixed emergence angle (α), is a combination of R_{NIP} and R_N , called R_{CDS} . So the traveltimes approximation of CRS will reduce to

$$t^2(x_m, h) = \left(t_0 + \frac{2\sin\alpha}{v_0}(x_m - x_0) \right)^2 + \frac{2t_0\cos^2\alpha}{v_0 R_{CDS}} \left((x_m - x_0)^2 + h^2 \right) \quad (2)$$

By separately considering each plausible emergence angle on a discrete grid, a sample in the ZO section will receive contributions of any possible optimum operator for each angle that we are searching for. Obviously, this enhances any weak reflection and diffraction events which were obscured by dominant coherent events in previous strategy. The strategy used here differs from the pragmatic strategy (Müller 1998) and the extended strategy (Mann 2002) in its way to find the optimum wavefield attributes. In this case, we require access to the entire prestack dataset from the very beginning, not only a subdomain of it.

Furthermore, neither the automatic CMP stack nor the ZO search steps are suited to address this problem. Instead, the only option is to directly go through the whole prestack data, and search for the only variable, the attribute R_{CDS} for each fixed emergence angle. The target zone, the aperture, and the range for minimum and maximum stacking velocity are defined in the same way as for the pragmatic search strategy. By implicit knowledge of the value of R_{CDS} , the shape of the operator could be defined in terms of a moveout range. By coherence analysis, the optimum value of R_{CDS} can be calculated in the next step.

Sigsbee 2A synthetic data

The so-called Sigsbee 2A data is based on a stratified background model containing a salt body with a quite complicated geometry. Figure 1 (left) shows the CRS-stacked section of the model created with the extended pragmatic search strategy. In the left part there are slightly dipping layers up to a time of 9 s ending with a strong reflection event. In the top right part there are also similar sedimentary structures which cover the salt body and with its small syncline structure. Strong, extended diffraction patterns dominate the central part of the section whereas some weak diffraction events can also be seen in the left and lower parts of the section.

The result of the CDS stack is shown in Figure 1(right). Compared to the result of the CRS stack, diffraction patterns are enhanced in all parts of the section. In particular in the sedimentary structures in the left-hand part, diffraction events which are partly or fully obscured by reflection events in the CRS-stacked section are clearly imaged. The lower right part of the CDS-stacked section have been removed before starting the main process to save computation time. In the CRS-stacked section, diffraction patterns are simulated but some of them have gaps where they intersect reflection event. These gaps correspond to the locations where the conflicting dip situations have not been properly detected during the stack.

In contrast, in the left-hand part of the result of the CDS stack, the continuity of events is fully preserved and there are no gaps on the diffraction events, even where they are intersecting other events.

Real land data set

The 2D seismic land dataset was acquired by an energy resource company in a fixed-spread geometry. The underlying structure consists of nearly horizontally layers and some dipping layers due to dip faulting in some parts. In CRS stack processing, mapping the position of faults, their boundaries, and their dips was difficult because the problem of conflicting dips also exists at the end points of faults and also where the layers are faulted.

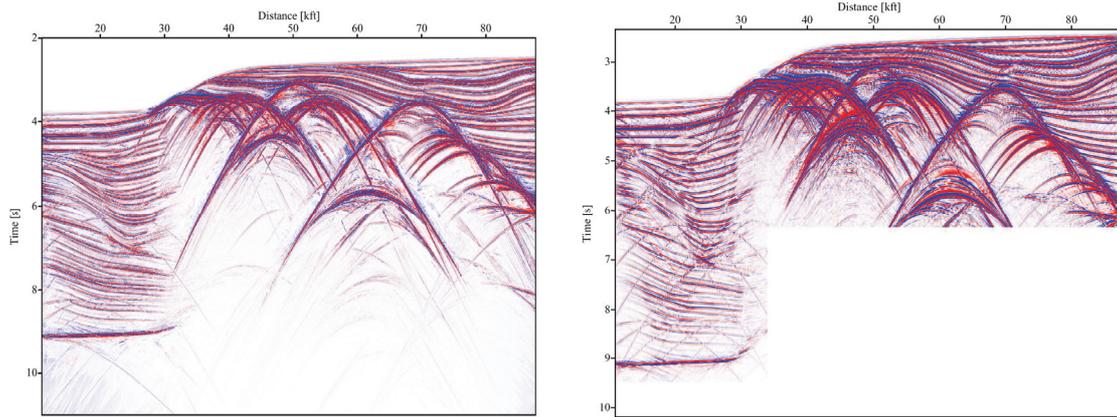


Figure 1, left) CRS-stacked section and right) CDS-stacked section of Sigsbee 2A.

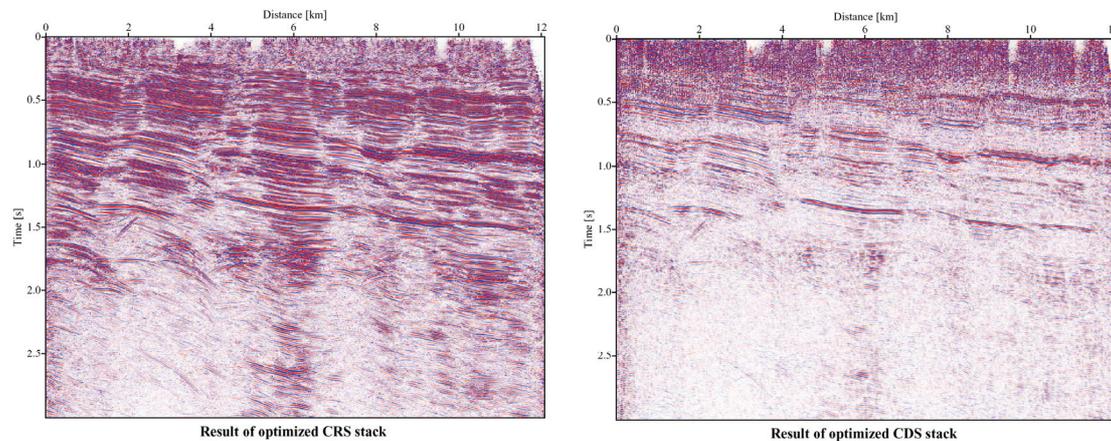


Figure 2, left) result of CDS stack and right) CRS stack for the real land data set.

Figure 2 shows the stacked results of the CRS procedure and the CDS results for these data. It could be seen that the diffraction events are again emphasized and the faults also appear clearer than in the pragmatic result. Figure 3 shows the results of the two different migration processes. The migration results of CDS-stacked section shows higher signal to noise (S/N) ratio. They also exhibit more continuity in the events, and a clearer localization of the faults than the conventional result. Some differences are marked by arrows. Most of the arrows are along the reflector that extends through the whole section at a depth of 1500m. This reflector is faulted in some parts such that the migration of the CRS-stacked section could not resolve the continuity of this event because of conflicting dip situations. The migration of the CDS-stacked section could resolve this problem in the faulting parts.

Conclusion

The pragmatic approach of Müller (1998) and the extended strategy of Mann (2002) have been combined with the concepts of DMO correction to overcome the problem of conflicting dip situations. In the new approach, the kinematic wavefield attributes are reduced to a combination of the radii of curvature of normal wave and NIP wave, called R_{CDS} , and the (fixed) emergence angle within a predefined range. The results of applying the improved strategy to synthetic data and real land data proved that this strategy could completely overcome the problem of conflicting dip situations and yields a stacked section with more continuous events and clearer images of (previously obscured) weak events.

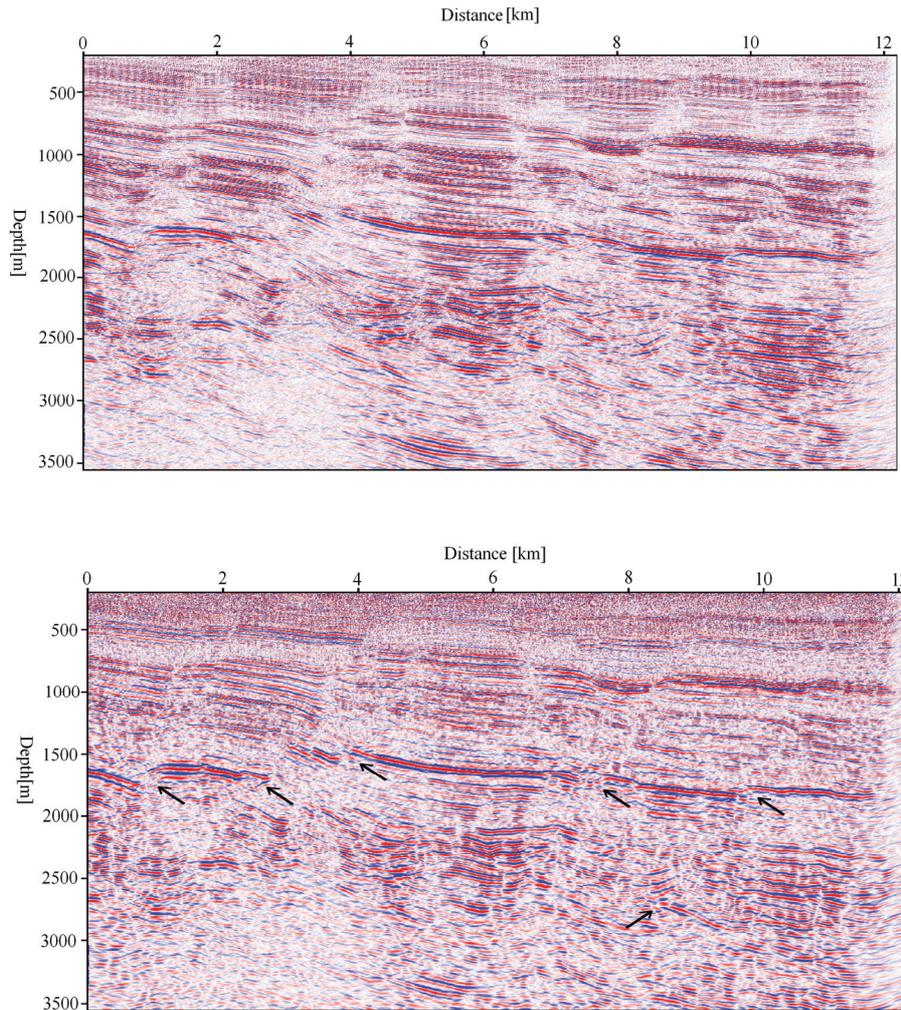


Figure 3, different poststack-migrated sections. top) migrated CRS stack result and bottom) migrated CDS stack result.

The results of poststack depth migration of a real land data set also proved that the CDS-stacked section provides suitable input for poststack migration.

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