CRS seismic processing: a quick tutorial

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Abstract

The aim of this work is to present an alternative way that could be introduced in the conventional seismic processing, using a macro model independent method. We will show how to take advantage of the results of this process to incorporate them in the normal flowchart of processing. We also present a didactic synthetic example to ilustrate how the flowchart works.

Introduction

In the last few years a new method to obtain a zero-offset (ZO) stack section was introduced in the literature: common reflection surface (CRS) stack (Mann et al., 1999). It is macro-velocity model independent method and has the advantage of using more traces than the conventional process. Moreover, the CRS stack method also provides several kinematic parameters, which can be used to invert a velocity model. Consequently, the introduction of the CRS method into the conventional seismic processing can be advantageous. This work presents an alternative flowchart seismic process based on CRS and totally model independent.

CRS method

The CRS method is based on a multi-parameter traveltime apprroximation, called the hyperbolic traveltime formula(Tygel *et al.*, 1997) which relates the traveltime of two rays. One of them is taken as reference ray, and is called central ray.In the CRS method, the central ray is chosen as a ZO ray and its reflection point is called Normal Incidence Point (NIP). The formula read

$$T^2(x_m,h) = \left(t_0 + \frac{2x_m \sin\beta_0}{v_0}\right)^2 + \frac{2t_0\cos^2\beta_0}{v_0}\left(K_N\, x_m^2 + K_{NIP}\, h^2\right),$$

where $x_m = (x_G + x_S)/2 - x_0$ and $h = (x_G - x_S)/2$, x_0 is the coordinate of the central point, x_G and x_S are the horizontal coordinates of the receiver and source, respectively,, t_0 the zero-offset two way traveltime, β_0 the emergence angle measured with respect to the normal surface,, K_{NIP} and K_N and two wavefront curvatures associated to two hypothetical eigenwaves N-wave and NIP-wave,Tygel et al. (1997), see Figure 1.

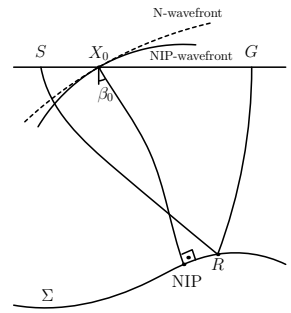

Figure 1: CRS Parameters for a normal central ray X_0 NIP X_0: the emergence angle β_0 and the NIP- and N-wavefront curvatures. Σ is the reflector, X_0 is the central point coordinate, and S and G are the source and receiver positions for a paraxial ray, reflecting at R.

Processing sequence

The process is the same as the conventional process up to NMO stack, which is automatically performed during the CRS stack. At the end, the CRS stack method came up with three parameter sections, one coherency section and, in general, a more accurate ZO simulated section. The most relevant aspect is that the whole procedure is completely velocity-model independent and a larger number of traces is stacked than in the conventional NMO/DMO process, increasing the redundancy and the signal-to-noise ratio.

Once a ZO section is available, the method also provides a Post Stack Time Migration, without the requirement of having a velocity model in time domain. This can be achieved using only the CRS parameters.

As we have just pointed out, the CRS parameters carry to much information about the media and then we should use this parameters as much as possible. Following this idea, the classical layer-stripping velocity inversion algorithm of Hubral and Krey (1980) can be recast by using

of the CRS (Biloti *et al.*, 2001). It inverts iteratively on the depth homogeneous layers and interface positions. The interfaces are constructed as cubic splines, which are suitable for further block ray tracing algorithms. This process involves low computational costs since the CRS parameter are already available.

Once we have the inverted velocity model, it is possible to perform a complete PreStack Depth Migration (PreSDM), using weights to compensate amplitudes for geometrical spreading. Also, an unweighted PreSDM can be realized followed by a *a posteriori* amplitude correction for some common-reflection points (CRP) gathers (Portugal *et al.*, 2001). This correction is performed in three steps: (i) for the selected depth point compute the traveltime, incidence angles and geometrical-spreading factors by modeling, using the inverted model; (ii) pick the amplitude from the original data, using the traveltime information and, (iii) multiply them by corresponding the geometrical-spreading. This CRP points are chosen in a unweigth PreSDM, which has the characteristic to show a good kinematic image of the subsurface. After the AVO/AVA curves are constructed.

Synthetic example

To illustrate the just described procedure, we show step-by-step how it works on synthetic data. Figure 2 shows the compressional velocity field of synthetic model. The shear-velocity at each point is set to the compressional velocity dived by $\sqrt{3}$. The model is composed by four layers bounded by

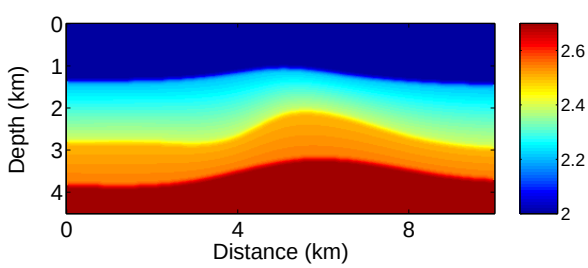

Figure 2: Synthetic model.

smooth interfaces. The top and bottom layers are homogeneous and the two intermediated layers are inhomogeneous both in x-direction and z-direction. The multicoverage data is formed by a collection of 150 common-offset section, with offset varying from 20 m up to 3000 m, with around 500 source-receiver pairs each. In Figure 3 we can see a typical common-offset section with offset 1500 m. The signal-noise ratio added to the data was 7:1.

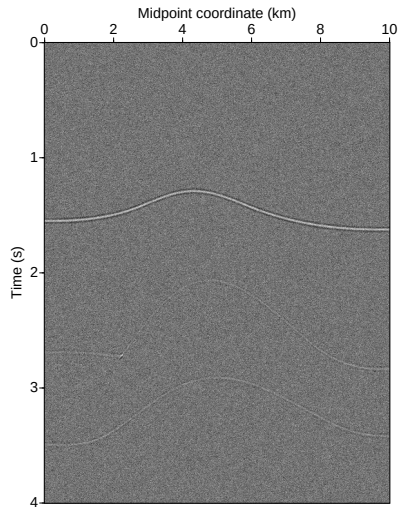

Figure 3: Example of a common-offset section.

After performing the CRS stack method, the obtained simulated ZO section is shown in Figure 4. Note the great improvement in the signal-to-noise ratio. As an example, Figure 5 presents one of the

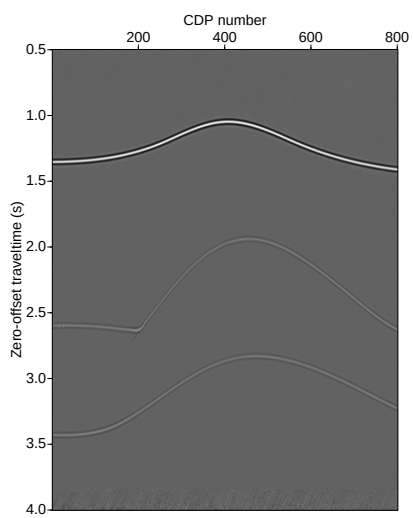

Figure 4: CRS simulated ZO section.

parameters section the emergence angle section. It is important to note that the parameter value for each point of the section make sense only if the point is indeed a reflection event. After the conclusion of the first step of the CRS, we directly proceed to the invertion step. In Figure 6 we show the inverted model where it is possible to observe that the recovered model fits very well the synthetic

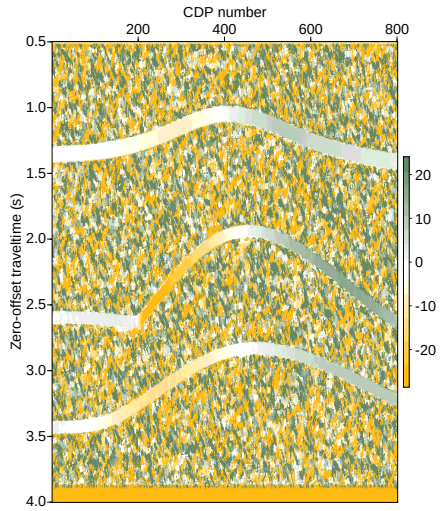

Figure 5: Emergence angle section

model, even in the inhomogeneous layers.

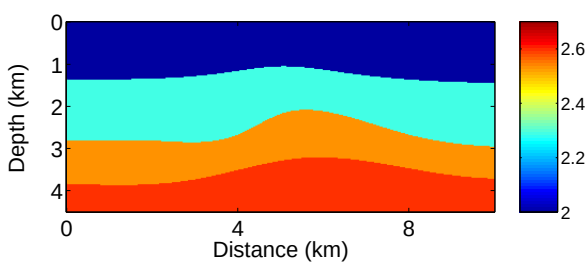

Figure 6: Inverted velocities model.

The velocity model is now smoothed in order to apply PreSDM, which is performed using the traveltime tables generated on the fly by wavefront construction method (Vinje *et al.*, 1993). Each common-offset section is migrated separately (see Figure 7), and then stacked migrated section, see Figure 8.

The stacked migration section does not have information about correct amplitudes, but it serves as an image to chose points (the CRP points) to perform the AVO/AVA curves. This is done as was discussed in the Processing Sequence section. The result for one ponint is show in Figure 9

Conclusion

The CRS method provides a powerful tool to process multi-coverage data. It allow us not only to obtain a good simulated ZO section, but also get a tool for the next steps in the conventional processes. One more interesting application, that we are working on is to incorporate the acquisition topography in the method. We hope to obtain good results in cases with strong variations in the acquisition surface.

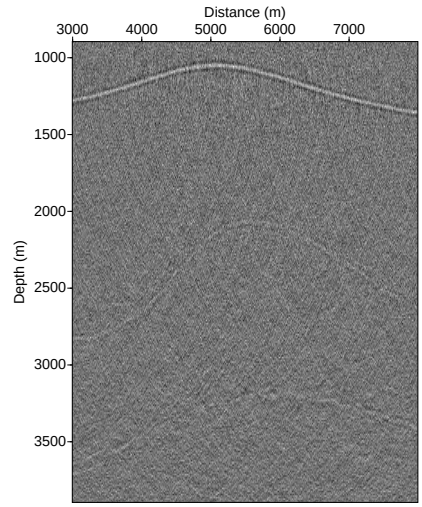

Figure 7: typical migrated section.

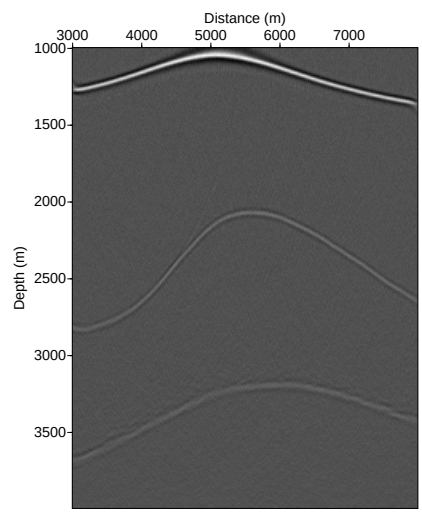

Figure 8: Stacked migrated section.

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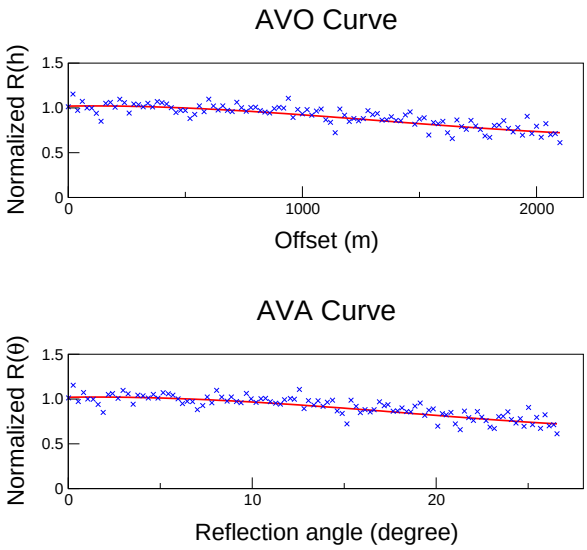

Figure 9: AVO/AVA for a point in the second interface.

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