Topographic effect correction using CRS parameters

Valeria Grosfeld, Ricardo Biloti, Lúcio T. Santos, and Martin Tygel

grosfeld@ime.unicamp.br

Abstract

The Common Reflection Surface (CRS) is a stacking process that simulates a zero-offset section and provides useful parameters sections. It can be applied to the real non horizontal measurement surface and it is necessary to remove the topographic effect to obtain a more accurate section to be interpretated. This work presents a new technique to remove the topographic effect: continuation of the information to a chosen depth datum using the CRS parameter. A synthetic example is provide to illustrate the approach.

Keywords: Redatuming, Common Reflection Surface method, topographic effect

1 Introduction

The CRS stack method simulates a zero-offset (ZO) section by summing along stacking surface in bidimensional multicoverage data (Birgin et al. (1999)). This data is supposed to be collected on the real earth surface. After CRS method is applied we obtain a stacked section simulated on an irregular surface. This fact affects any further interpretation, and then, it is necessary to remove the effect of the measurement surface.

We will show that, once we have already made an effort to estimate the CRS parameters to construct a zero-offset section, we can use them to redatuming the stacked section (and also the parameter sections too) to a chosen depth datum.

The moveout formula employed in the CRS method, known as hyperbolic traveltime (see, for example, Tygel et al. (1997)), is given by

$$T^2(x_m,h) = \left(t_0 + \frac{2x_m \sin\beta_0}{v_0}\right)^2 + \frac{2t_0\cos^2\beta_0}{v_0}(K_N x_m^2 + K_{NIP}h^2), \tag{1}$$

where

$$x_m = \frac{x_G + x_S}{2} - x_0 \quad \text{and} \quad h = \frac{x_G - x_S}{2}\,,$$

x_S and x_G are the x coordinates of the source and receiver, respectively, t_0 is the two-way zero-offset traveltime, β_0 is the emergence angle of the normal ray, and K_{NIP} and K_N are the NIP- and N-wavefront curvature measured at the central point, respectively, and v_0 is the near surface velocity. This formula does not take into account the curvature of the measurement surface. After the application oh the CRS method we obtain four sections: one for the stack, one for the emergence angle and two for the curvatures.

2 Redatuming

In this section we discuss how to use the CRS parameters to remove the topographic effect. Once we have the CRS sections on the measurement surface, $z = \Sigma_0(x)$, we select a horizontal datum, $z = z_d$, to "continue" the information, see Figure 1. To simplify the problem, the new measurement surface is above the actual one. Furthermore, the velocity of this artificial homogeneous layer is constant and equal to the near-surface velocity v_0. In this way, we can propagate the normal rays up to the datum, since we know the normal to the surface and the emergence angle β_0 for each point at measurement surface.

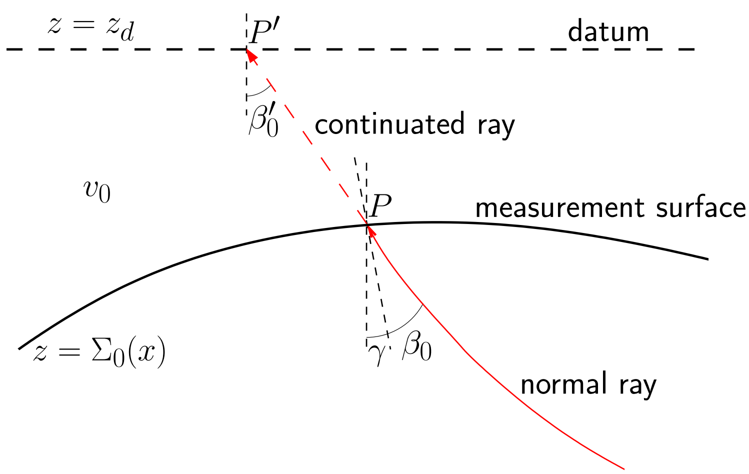

Figure 1: Redatuming scheme. Continuation of a normal ray (red solid line) that hits the measurement surface Σ_0 at P up to P', on the datum at depth z_d, as a straight segment (red dashed line). β_0 and β_0' are the emergence angle at P and P', respectively. γ is the angle between the normal to the measurement surface at P and the vertical axis.

Referring to Figure 1, let us denote by $P = (x_0, \Sigma_0(x_0))$ a point on the measurement surface where we have simulated a zero-offset trace and by $P' = (x_0', z_d)$ the point on the datum where the normal ray arrives after redatuming. Therefore,

$$x_0' = x_0 + (z_d - \Sigma_0(x_0)) \tan(\beta_0 + \gamma), \tag{2a}$$

and the new CRS parameters are

$$\beta_0' = \beta_0 + \gamma, \tag{2b}$$

$$t_0' = t_0 + \frac{2|P - P'|}{v_0}, \tag{2c}$$

$$\frac{1}{K'_{NIP}} = \frac{1}{K_{NIP}} + |P - P'|, \tag{2d}$$

$$\frac{1}{K'_N} = \frac{1}{K_N} + |P - P'|, \tag{2e}$$

where $|P - P'|$ is the distance between P and P' and γ is the angle between the normal to the measurement surface on P and the vertical axis. Applying this formulas to the whole section completes the redatuming.

3 Resampling

In the previous section we have shown how to correct the information of a point P at the measurement surface to a point P' at the depth datum. Although the central points at the measurement surface were, in general, regularly sampled, the continuated points are irregularly spread at the datum. Indeed, each CRS attribute and stacked amplitude, associated to a pair (x_0, t_0) on a regular grid, is mapped onto a new location (x'_0, t'_0), defined by equations (2a) and (2c). The set of all pairs (x'_0, t'_0) is no longer a regular grid. For image purposes only, this is not a serious problem. But if we aim to further process the continuated zero-offset section, it is necessary to interpolate this information back to a regular grid.

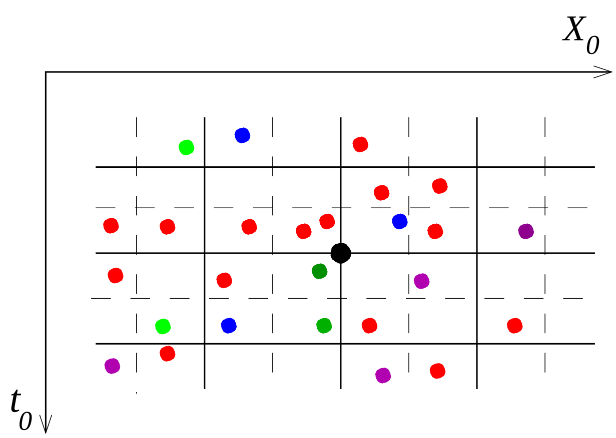

Figure 2: Resampling scheme. Solid lines: new regular grid. Dashed lines: vicinity around each grid point of the regular grid.Colored bullets, continuated quantities. Black bullet, point where the information are interpolated.

To resampling the information we employ a simple, strategy, depicted in Figure 2. The colored bullets state for the continuated points at the plane (x_0, t_0). The solid lines represent the regular grid where the information should be recast. To determine the amplitude of a point at the new grid (depicted as a black bullet), we perform an average of all values associated to points inside a certain vicinity of it. This vicinity is taken as rectangle centered at the desired point, represented by dashed lines in Figure 2.

4 Synthetic example

The process was applied to the model shown in Figure 3, consisting of two interfaces, separating three homogeneous layers. Note that the measurement surface has a sinusoidal shape. The bidimensional elastic data was modeled with the dynamic ray tracing package by Červený (1985).

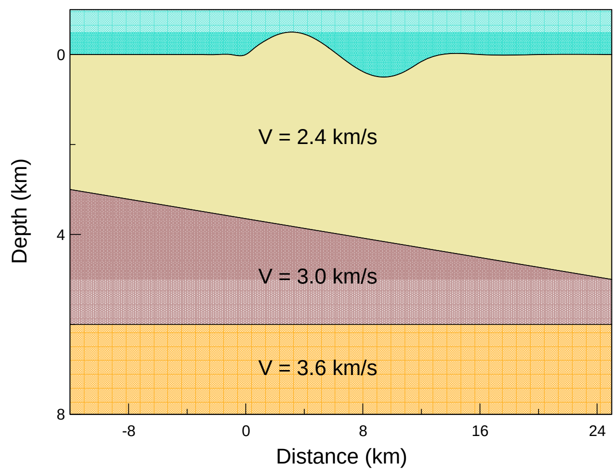

Figure 3: Synthetic model with three homogeneous layers.

Figure 4 clearly shows that the obtained CRS stacked section is affected by the topography. In order to apply the proposed strategy, we have chosen a datum at $z = -1$ km. The continuated stack is depicted in Figure 5(a). As we could expect, the reflections of the plane interfaces become straight. As a verification, we have modeled the zero-offset section acquired at the datum (Figure 5(b)). A very good kinematic agreement is observed. As a validation of the parameter values, we can observe Figure 6(a), where is depicted the emergence angle section, showing the angle variation along the reflectors. On the other hand, in Figure 6(b), we can seen that, along the reflection location, the parameter value is practically the same. This behavior is in concordance with the fact that we have plane reflectors.

5 Conclusions

We have presented a strategy to correct the topographic effect after the naive application of the CRS method. The corrections are carried out not only on the stacked section but also on the attribute panels.

The results are encouraging concerning kinematic accuracy. The emergence angles were correctly recasted. Nevertheless, the eigenwave curvatures still presents some variations along the reflection location that are not consistent with the theoretical values. This could be explained by the physical derivation of the hyperbolic traveltime moveout formula, which does not take into account the curvature of the measurement surface. Chira et al. (2001) have recently addressed this problem, proposing a new moveout formula to correct for non-planar measurement

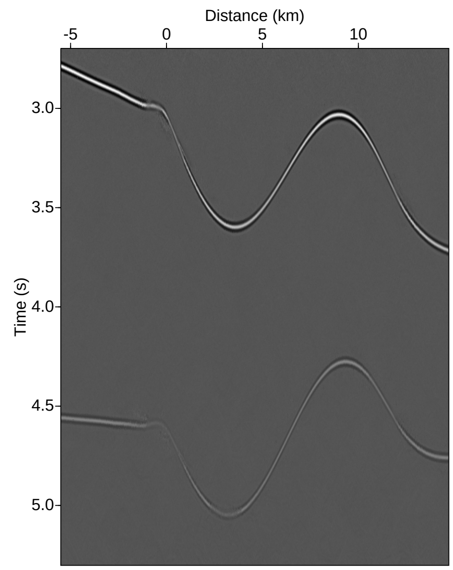

Figure 4: CRS stacked section.

surfaces. Anyway, it is necessary to remove the influence of topography. Since the proposed strategy depends only on emergence angles, it can readly applied even with this new traveltime approximation.Further tests in real data will be carried out.

6 Publications

This work is the product of the Master Thesis of Valeria Grosfeld (Grosfeld (2001)). Some parts of it were presented at the 7th International Congress of the Brazilian Geophysical Society, Salvador, Brazil (Grosfeld et al. (2001)).

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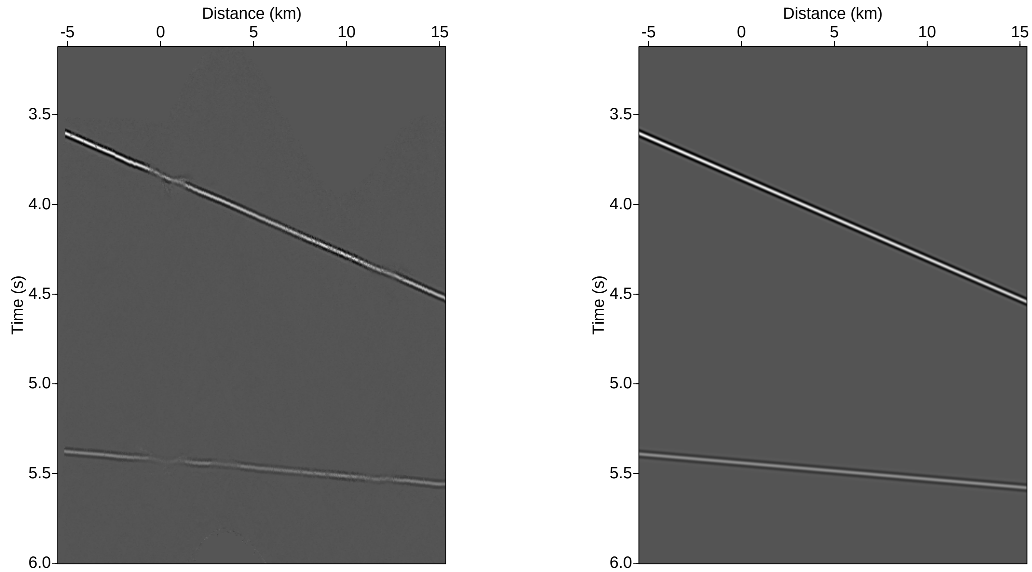
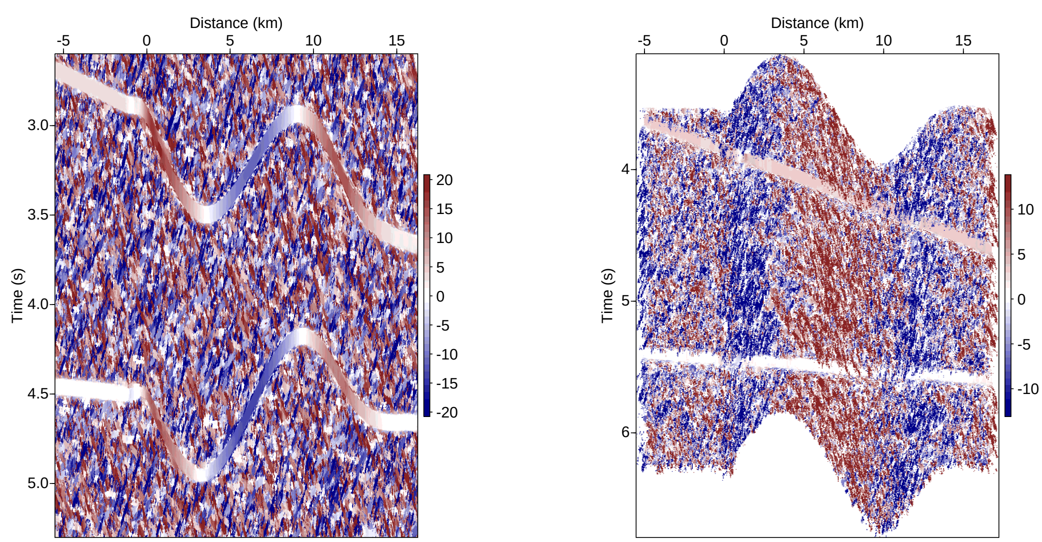


(a) Continuated. (b) Modeled.

Figure 5: Zero-offset sections.



(a) Obtained by the CRS method. (b) Continuated.

Figure 6: Emergence angle sections.

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