Local Stretch Zeroing NMO Correction

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Summary

In this paper we present a new method of normal move-out (NMO) correction called local stretch zeroing (LSZ) method that avoids NMO stretch. The method eliminates the theoretical curves that generate interpolated data samples responsible for NMO stretch. Pre-correction time sampling interval is preserved by reassigning and zero padding of true data samples. The optimum mute zone selection feature of the LSZ method eliminates all interfering reflection events at far offsets. The resulted stacked section from the LSZ method contains generally higher frequency components than a normal stack, and preserves most of the shallow reflectors.

The LSZ method requires that zero-offset width of the time gate, i.e. zero-offset time difference between two adjacent reflections, be larger than the dominant period. The major shortcoming of the method occurs when CMP data are over- or under-NMO corrected. Real world examples show the efficiency of the LSZ method over the conventional NMO (CNMO) correction.

Introduction

In the seismic record of a 1-D Earth model, reflection events appear coherent and in hyperbolic form. The normal move-out (NMO) correction is applied to transform traces recorded at non-zero offset into traces that appear to have been recorded at zero offset. Semblance based methods are often used for calculating NMO velocities. As shown by Buchholtz (1972), the conventional application of the NMO correction to a CMP reflection generates a stretch which increases with offset and decreases with zero-offset time. This is the major shortcoming of the CNMO method. The discussion on the effect of NMO correction on reflection data has always been a topic of interest. To improve the CNMO method, Causse et al. (2000) proposed a large-offset approximation scheme for seismic reflection traveltimes. Taner & Koehler (1969), Al-Chalabi (1973) and Gidlow & Fatti (1990) applied corrections using an order higher than 2. To perform non-stretch NMO correction, de Bazelaire (1988) proposed the shifted hyperbolae method. In this formulation, the scanned parameter is the focusing time of the hyperbola, instead of the NMO velocity. Rupert & Chun (1975) introduced the block-move-sum (BMS) concept, which applies a series of static shifts to blocks of data followed by summation. BMS has been the subject of further developments, as was recently reviewed by Brouwer (2002), where an up-to-date list of references can be found. Also, Perroud & Tygel (2004) proposed a non-stretch NMO to automatically avoid the undesirable NMO stretch. In this study we present a new stretch free NMO correction method. The method improves the conventional procedure by optimum selection of mute zone and complete elimination of interpolated data samples (for more details see, Kazemi and Siahkoohi, 2012).

Theory

In this section we describe the local stretch zeroing *NMO* correction method step by step. Assume a *CMP* gather with (*n*) seismic reflection events $(h(t_{0i}, v_i), i = 1, 2, ..., n)$ and corresponding velocity model determined by linear interpolation of picked *NMO* velocities. It is worthy to mention that the *LSZ* method does not assume all theoretical curves to be hyperbole rather it assumes they are fairly in accordance with reflection events on the *CMP* gather.

Based on the picked velocities, *CMP* gather is divided into (*n-1*) time gates. The i^{th} time gate consists of data samples confined to the theoretical curves, $h'(t_{0i}, v_i)$ and $h'(t_{0(i+1)}, v_{i+1})$, corresponding to zero-offset times t_{0i} and $t_{0(i+1)}$ respectively *(Fig.1(a))*. To eliminate the *NMO* stretch from i^{th} reflection event within the i^{th} time gate, the proposed method performs as follow:

1. Based on the velocity model, a theoretical curve is attributed to each zero-offset time data sample of the gate. The *LSZ* method selects the first theoretical curve $(h'(t_{0i}, v_i))$ as a base curve $(i.e. h'_{b1})$. Later on, time differences between the base and the rest of the curves are measured at a given offset *X*.

2. At offset *X*, those theoretical curves that their time differences do not exceeds the half of the sampling interval, $\Delta t/2$, are removed. This avoids generation of new (or interpolated) data samples (e.g. s'_1 and s''_1 in *Fig.1(b)*) due to the interpolation during NMO correction which is usual in CNMO.

3. Whenever the method reaches a theoretical curve with time difference greater than the half of the sampling interval, it is considered as a new base theoretical curve (h'_{b2} instead of h'_{b1}) and comparison is continued.

4. Steps 2 and 3 are stopped when the algorithm reaches to the end of the time gate or theoretical curve $h'(t_{0(i+1)}, v_{i+1})$, (*Fig.1(a)*).

5. Using the preserved theoretical curves, CNMO is applied on the CMP data within the i^{th} time gate. Obviously, the corrected data samples will be irregular and their time intervals may be greater than or equal to the pre-correction sampling interval. The LSZ method by reassigning data samples, regularizes them to the pre-correction sampling interval. For some offsets, it may be needed to pad the end of the time gate with zeroes (Fig.1(b)). The number of padded zeroes will be equal to the number of deleted theoretical curves.

Examples

To evaluate the performance of the *LSZ* method in comparison to the *CNMO*, we applied both methods on real seismic data. We selected *65 CDP* gathers from a real data set. The *CDP* gathers have fair amount of far offset traces (Up to *18Km*). Figures *2(b)* and *2(c)* present the stack sections of the *CDP* gathers after applying *LSZ* and *CNMO* methods, respectively. We used the same RMS velocity model, as shown in *Fig. (2a)*, to perform NMO corrections. All the processing steps but the *NMO* correction method were kept same for both sections. In the case of *CNMO* method, onset of the mute zones defined manually, but in the *LSZ* method onsets were selected automatically. Recalling the harmful effect of *NMO* stretch, it is clear from Fig. *(2)* that the stack section of the *LSZ* method has higher resolution and shallow reflectors are strongly preserved, but in that of the *CNMO*, due to further muting of large-aperture traces in shallow region (Stretching), reflectors thoroughly degraded. It is worthy to mention that the *LSZ* method requires the onset of the time gates to be picked interpretively. False picks may degrade the characteristic of reflectors in the stacked section.

Conclusions

The *LSZ* method introduced in this paper performs stretch free *NMO* correction and maintains true data samples of the full wavelet up to onset of the mute zone. To enhance the stack energy and improve the quality of the stacked section, at offsets beyond the onset of the mute zone, the *LSZ* method drops the interfered data samples.

In proposed method, for non-stretch *NMO* correction, the linear data interpolation step of the *CNMO* method is replaced by following steps: elimination of some theoretical curves, reassigning true data samples, and zero padding. The method is able to automatically determine the optimum mute zone of each reflection event. This advantage of the method permits muting to start exactly from an offset where the events are about to interfere. Due to the lack of degrading and stretching, resulted stacked section of the *LSZ* method from real data set has higher resolution than normal stack and clearly captures shallow traps.

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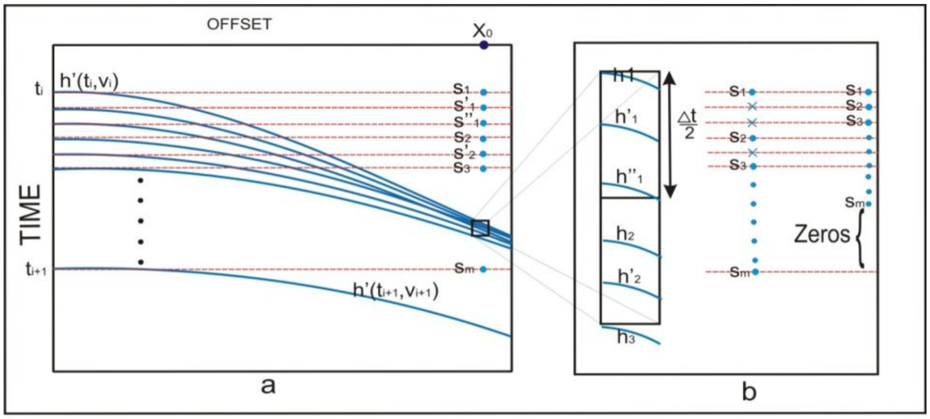

Fig 1. *(a) Theoretical curves* $h^{'}(t,v)$ *within the* i^{th} *time gate of a CMP gather which is limited to zero-offset times* t_i *and* t_{i+1}*. Dashed red lines show the curves after CNMO correction. At a given offset (e.g.* x_0*)* (s_i) *'s are NMO corrected data samples. These* (s_i) *'s are true data samples that correspond to the preserved theoretical curves. However,* $(s_i^{'})$ *'s are data samples that generated during CNMO correction by linear interpolation. (b) A zoom into the portion of the time gate in (a) indicated by a little black square, with length equal to sampling interval* Δt*. The blue dots at the middle of the figure indicate NMO corrected data samples corresponding to the preserved curves. While, the blue crosses indicate the position of those data samples that were not generated due to the lack of linear interpolation step in LSZ method.*

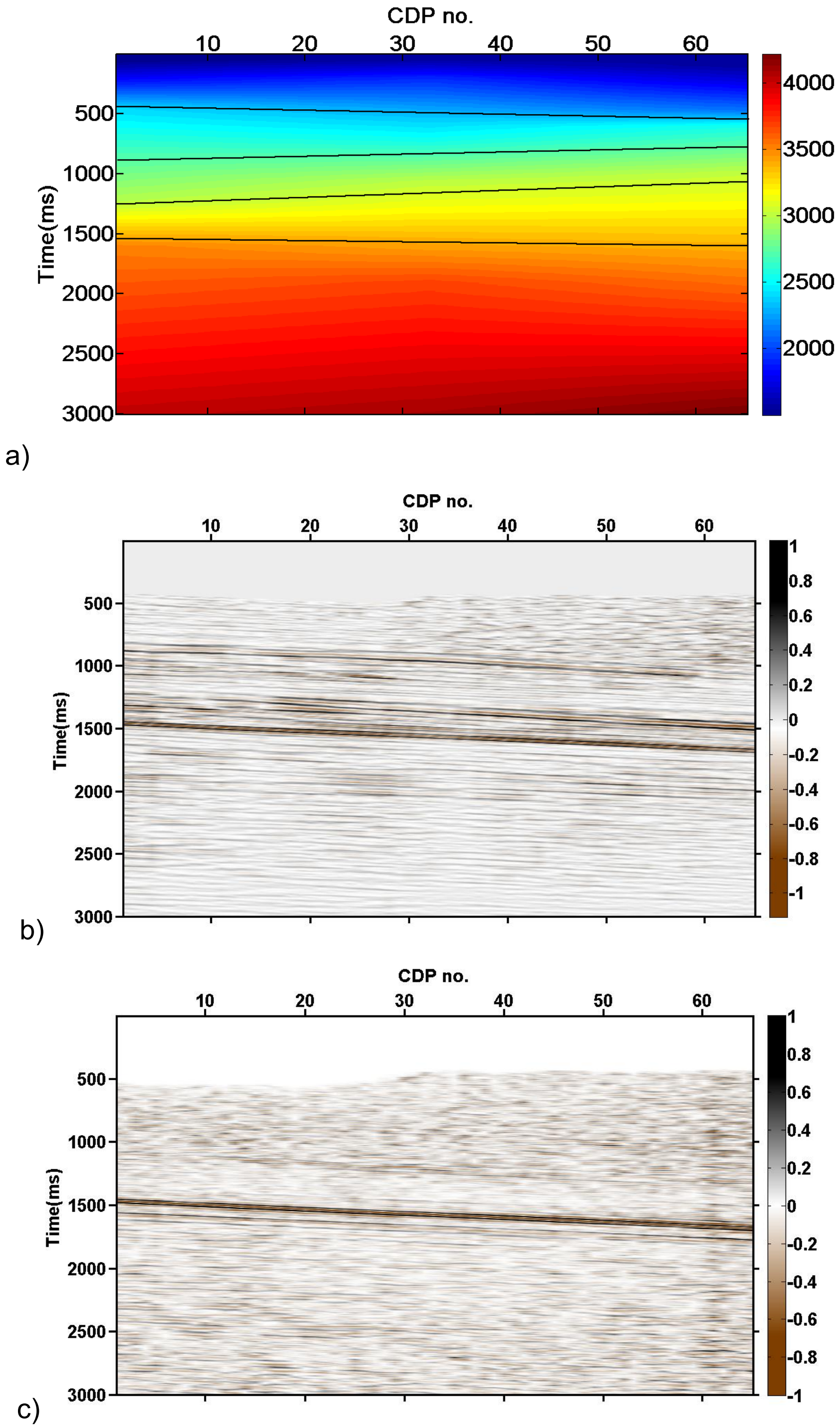

Fig 2: *a) The velocity model used for NMO correction and kept same for both methods (Solid lines show the boundary of sharp variations in velocity gradient), b) The LSZ stacked section, and c) The CNMO stacked section.*