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Flexibinning Versus Prestack Interpolation: An Analysis

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Summary

Multi-steamer surveys are although highly cost effective but bear inherent weaknesses which bring a significant degradation in quality of seismic imaging. As the marine seismic surveys are designed with single cross foldage, for obvious reason it can be understood that near offset will be missing on the subsurface line generated from the steamer away from the source line. Hence alteration in the foldage is obtained parallel to sub-line causing heavy footprints at least in the shallower section of the volumes. Moreover, various conditions such as severe marine current, cable feathering, economic constraints and obstruction result gap in coverage and irregular trace spacing.

In this paper the negative impact of the flexi binning is analyzed and Pre-stack Interpolation is used to interpolate the missing traces to regularize the data set within pre stack trace gathers. As far as missing traces are concerned, interpolation appears to be superior solution. Pre-stack Interpolation estimates the coherent components for the traces in the gate centered at the output interpolated trace location along a moving window of the size of the spatial gate at each of the dips specified by maximum dip and maximum frequency used in the data analysis. The two neighboring input traces are then used to interpolate or extrapolate the output trace along the coherent dips. Interpolation is used when the new output trace lies between two neighbouring input trace .Extrapolation will be used if there are not trace on both side of the output trace but at least two traces exist on either side of the output trace. This method is applied to a marine data set of West Coast, India. The field example shows that the pre stack trace interpolation can lead to considerable improvement in the final processed image

Introduction

In his classical paper Mayne (1962) introduce CDP technique with the assumption of regular distribution of offsets within a CDP gather, it may produce many advantages like enhancement of S/N ratio by out of phase stacking of multiples and in phase stacking of primaries. This technique was basically designed for 2D surveys, which can easily be tuned to yield constant foldage and regular offset distribution at constant interval within a CDP gather along whole line. Conventional 3D-designs awfully fail to generate constant foldage and offset distribution along all the bins. Problems become more severe due to variation of source – receiver azimuths within the bins. Sym-Samp 3D technique suggested by Vermeer (2002) handles these problems in land 3D efficiently. It may be able to produce regular offset and azimuth distribution within the 3D bin. However this technique is less popular due to cost factor. During 3D marine seismic surveys various conditions such as severe marine current, cable feathering, economic constraints and obstructions result gap in coverage and irregular trace spacing. Beside these, multi-steamer surveys bear inherent weaknesses which bring a significant degradation in quality of seismic imaging. As the marine seismic surveys are designed with single cross foldage, for obvious reason it can be understood that near offset will be missing on the subsurface line generated from the steamer away from the source line (Fig.1). This introduces artifacts/noise that can limit the resolution of the final image and effect is especially pronounced in pre-stack imaging.

In nut shell, we may have two types of distinct problems in any data – first is presence of more than one trace per offset class and second is absence of some offset classes in 3D bins. These problems are handled by borrowing traces from adjoining bins i.e. Flexing the bin size or with Pre-stack

interpolation of missing traces. Normally these problems may be handled in flexibinning by two-tier flexi binning approach as follows.
A: Static Flexibinning
B: Dynamic Flexibinnig

Flexibinning and Pre-stack Interpolation

Static binning is targeted to handle the excessive foldages i.e. the presence of more than one trace in a given offset class within the bin. In this process any one trace is retained and others are dropped from the bin.

Dynamic binning is targeted to handle the holes in offset distribution. In case when a certain offset class is absent in a given bin, it is borrowed from the surrounding bin (Fig3).

We can evaluate the impact of flexi binning on processing output. One has three different choices in processing flow

NMO/DMO Stack – Post Stack Migration

Pre Stack Migration and then Stack

Although first choice is obsolete and no one prefers in general baring the exceptional cases of very low S/N ratio data in complex areas, causing migration smiles in DMO or PreSTM. In this approach when stacking is directly done after flexibinning, it has a power to dramatically increase the character continuity of the stack data yielding a first order improvement in its interpretability. In case of NMO stack a processor do not have any other option than flexibinning to fill the gaps in the offset distribution within the bins.

But this process has certain disadvantages, which may sometime degrade the stack response. In case of dynamic binning when a hole is filled by borrowing the trace from adjacent bins , no care is taken to adjust the phase and amplitude of the events in such reallocation, which may cause smearing in the stack response and may act as high cut filter. It would have been better to interpolate the trace instead of lending / borrowing based on the prevailing dips and source receivers azimuths. This process may have facilitated to overcome the problem of smearing and spatial aliasing in the stack response.

In case of static banning one trace is being retained on basis of certain criteria like proximity to bin center or so and dropping the others. The dangers involved with this technique may be very well understood by a simple example illustrated in fig2. The good quality traces may be thrown out at the cost of poor quality traces. It would have been better to retain vertical sum of all trace instead of retaining any one and dropping others. There may be two better options available with us one is to obtain a partial stack in the offset class or to allow the stacking software to handle redundant traces by giving them proper weights. The second option requires additional machine time.

Need of all offset classes during velocity analysis is cited another advantage of flexibinning in 3D processing, but supergather formation in both inline and crossline directions -implemented by most of the software- may handle the same.

The negative impact of the flexi binning during Pre Stack Migration can be easily understood through Fig.4. In this figure both the sections represent a common offset gathers in a 2D line. To find out PreStack migration output at point "A", the samples falling on the diffraction hyperbola are summed up. The top section shows non availability of particular offset class at cdp "n+1". Sample "s1" of trace at cdp "n" is falling on the hyperbola and therefore being included to calculate to find out migration out put at point "A". The bottom section shows situation after flexi binning, the trace at "n" is copied and borrowed to cdp "n+1". Now we find that sample "s2" of the trace is also contributing the response at point "A". The two samples, i.e., s1 and s2 of the same trace are contributing the response. It may cause mis postioning, smearing of amplitudes and loss of higher frequencies and probably spatial aliasing too. Overall imaging is also bound to deteriorate under effect of dynamic flexing. As for as need of static binning is concerned, the problem of handling multi traces per offset bin is also no more a issue in Pre-Stack Migration, since elegant trace weighting schemes are being implemented in such techniques e.g. the scheme using Vornoi diagram. Although retention of multi traces per offset classes may increase the load on the machine but able to avoid risking the superior traces being dropped as explained in Fig.2.

As far as missing traces are concerned, interpolation appears to be superior solution. However, pre-stack 3D interpolation is a costly affair and may involve large computing resources. The pre-stack interpolation may be attempted in gather domain but it has its inherent weaknesses-

1. Total gap on a particular CDP will not generate any offset, if process is attempted on a CDP gather.
2. Within CDP gather higher dips on NMO uncorrected gather may cause aliasing problem in interpolation.

On the other hand post stack interpolation appears to be comparatively easier and less error prone task. Drawing an analogy the pre stack interpolation may also be attempted on individual offset volumes since offset sorted volumes are very close to stack section. Interpolation related problems can be minimized once it is attempted in offset sorted volumes. Offset sorted volumes are having lesser amount of slope variations along reflectors as compared to

CDP domain, this will minimize aliasing problems while interpolating. It will also allow the holes even on the CDP location with zero foldage. In such cases interpolated traces will be based on the phase / amplitudes of neighboring bin. The only problem in such cases is data management.

Example:

In the current study, a 3D volume of West Coast, India has taken for pre stack interpolation, is used to demonstrate the effect of missing traces in the CDP gather, on the stack and the pre stack migration. The volume is approximately 13040 LKM with lot of offset gaps in the volume because of multi-steamer deployment and missing offsets. A missing trace interpolation method Pre-stack Interpolation is used to eliminate some of the problem encountered.

Water depth in the prospect area is varying from 12m to 30m. The 3D data acquired by deploying 6 steamers each having 240 channels at a group interval of 25m and 2 air gun arrays firing at 25m interval alternately (flip-flop). The nominal fold of the data is 51. The nearest and largest offsets are 144m and 5240m respectively.

Sorted CDP gathers from 3D volume has been subdivided into offset classes. Accordingly 49 nos. of 3D sub volume generated for offset classes of 200-5000 meters. Each offset cube has been undertaken for interpolation of traces for each CDP in two steps. First, offset cube sorted by subline as primary key and xline as secondary key has been taken for interpolation; this may generate many missing traces but still some gaps may occur at some locations which may be filled up in the second round of interpolation with offset volume sorted as xline & subline as primary and secondary keys.(Fig 5.). To obtain the interpolated traces, the coherence function is evaluated for all dips, the peak coherencies are found and interpolated to their exact dip values, and then sorted from largest to smallest coherency values. By examining the coherency and its ratio to other picked coherencies, the module then determines how many dips should contribute to the interpolation for the corresponding output sample. The two nearest traces then used to interpolate along the automatically picked dips to create the output sample value. This process is repeated for each output sample.

Analysis:

1. As an example of the interpolation of data with Pre-stack Interpolation, Fig. 6 shows two images for a CDP gather where missing offsets are filled during interpolation. Notice how the Pre-stack Interpolation application improves the signal to noise ratio and reflection events look more coherent and so can be easily interpreted.

2. Pre-stack Interpolation effectiveness was evaluated first by visual comparison of seismic section and time slices before and after Pre-stack Interpolation. Fig. 7 shows an inline NMO stack before and after Pre-stack Interpolation. Appreciable improvement in the overall signal to noise ratio after Pre-stack Interpolation is evident. Also, notice how the missing data gaps get filled up after Pre-stack Interpolation and reflections look more coherent and amenable for better interpretation.

3. Fig. 8 shows amplitude time slice at 1000 ms taken from 3D PSTM volume before and after interpolation. Notice the improvement in time slices is obviously seen. Footprints are not seen in time slice after interpolation.

4. Fig. 9 shows an inline PSTM section before and after interpolation. Image has become sharper after trace interpolation. The reflection event at shallow level looks more focused and continuous.

In view of the discussion held above, authors feel that flexi binning is an obsolete concept and should be avoided. Redundancy of traces should be obtained through weight calculation schemes (an alternate to static flexi binning) and offset gaps should be filled through pre-stack interpolation in the different offset volumes, as they nicely generate traces with due respect to source-receiver azimuth, phase and amplitude corrections (an alternate to dynamic flexi binning).

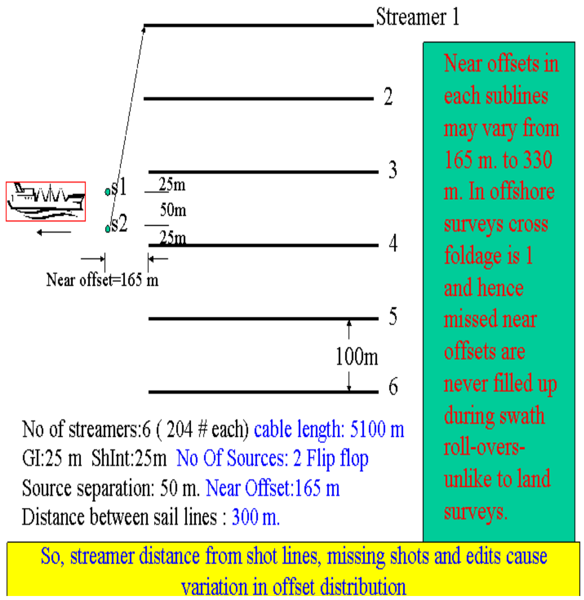


Fig.1: Offset distribution –absence of near offsets at sublines away from shot

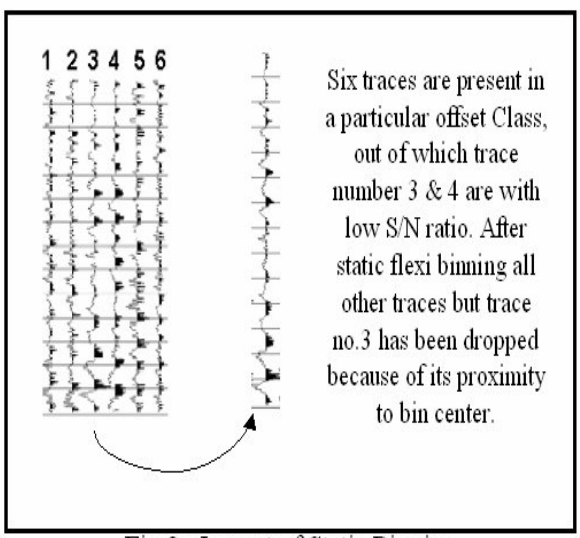


Fig.2 : Impact of Static Binning

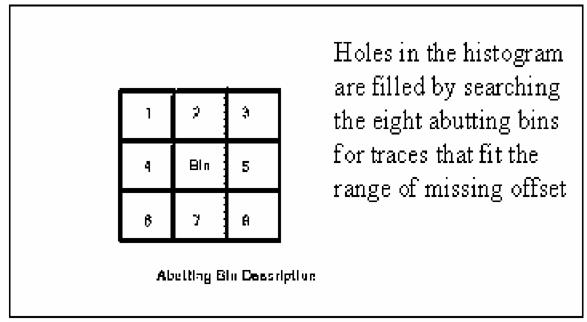


Fig 3: Dynamic Binning

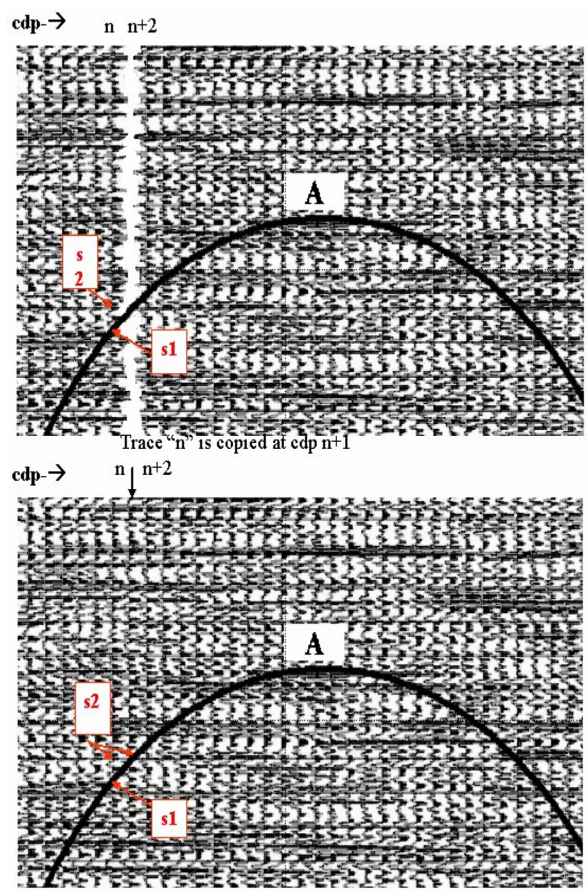
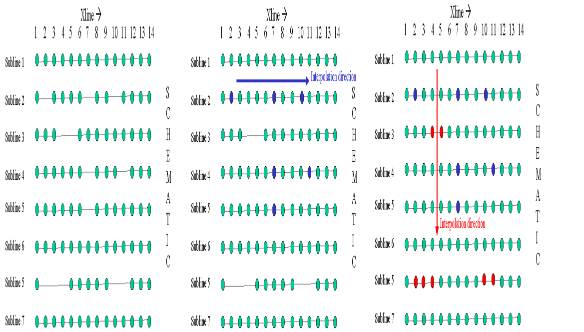
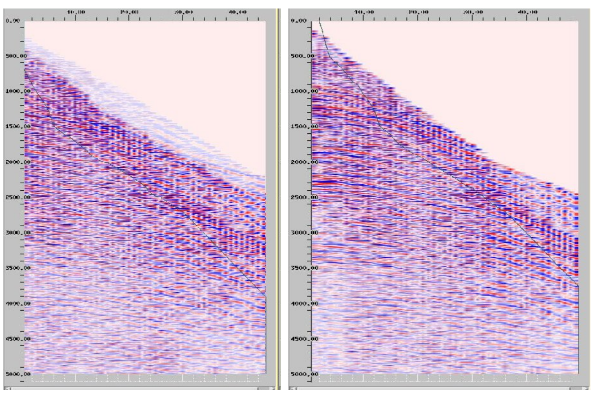


Fig 4. Impact of Flexi Binning During PreStack Migration. The top section shows a common offset gather and diffraction hyperbola. The missed trace is filled through flexing. This process has caused inclusion of two samples s1 and s2 from the same trace to get the response.



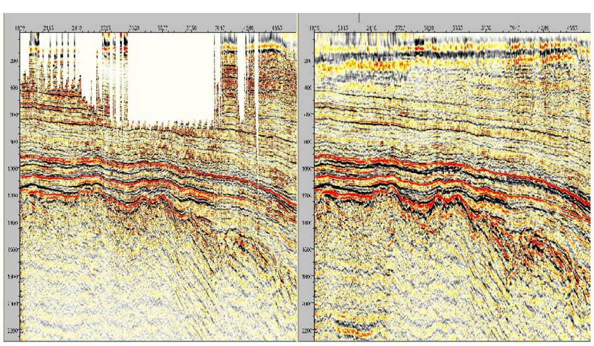
(a) (b) (c)

Fig.5: Offset volume showing missing traces (a), interpolation along inline direction (b) and interpolation along xline direction (c)



(a) (b)

Fig 6: CMP Gathers before (a) and after (b) pre-stack interpolation**.** Missing offsets are filled after interpolation and the signal to noise ratio are improved



(a) (b)

Fig 7: Inline NMO stacks after flexi binning (a) & after interpolation (b). Missing data gaps get filled up after Pre-stack Interpolation and reflections look more coherent

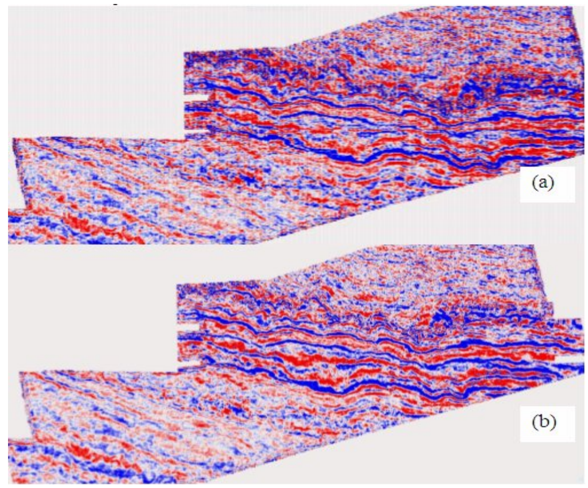


Fig 8: Time slice at 1000 ms before (a) and after (b) interpolation. Footprints are not seen in time slice after interpolation

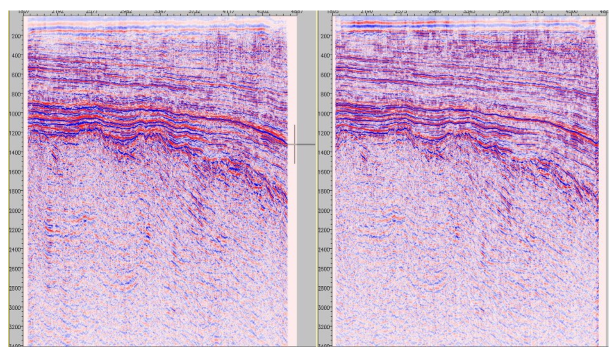


Fig 9: Inline PSTM section before (a) and after interpolation (b).The reflection event at shallow level looks more focused and continuous

Conclusion:

The pre-stack trace interpolation technique used for filling the gaps and missing offsets has appreciably improved the processed image thereby leading to a meaningful interpretation. In addition, it has effectively removed acquisition footprint which may be a hindrance to subsequent attribute analysis. The example presented in this paper shows that flexbining should be avoided and pre-stack interpolation should be attempted on offset volumes. Filling the holes on offset volumes has yielded better results.

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