SBGf35999

Horizon picking for multidimensional data: an integrated approach

N. Bienati, M. Nicoli, and U. Spagnolini

Dip. Elettronica e Informazione

Abstract

3-D seismic surveys generate 5-D data volume. In order to estimate the horizons for interpretation and further processing, the traveltime picking needs to be performed on n-D subsets of this 5-D data volume (n≤5). Horizon picking (HP) is complicated by the irregular sampling, faults, discontinuities, and low signal-to-noise ratio areas. The automatic HP techniques described here are aimed to support the interpreters in the estimation of the events by preserving their depth continuity. The HP is carried out directly on the full n-D dataset and not just iterated on 2-D sliced subsets, this avoids misties among different 2-D slices. The additional advantages are that the proposed method can perform the HP of multiple and irregularly sampled horizons, in addition it can handle discontinuous events by keeping the association with the target in depth. The interpreter is only asked to initialize the HP by providing some seed picks on the target horizon(s), then the algorithm lets the estimate of the horizons grow along all the dimensions simultaneously.

AUTOMATIC HORIZON PICKING FOR n-D DATA

In 3-D seismic surveys, horizon interpretation is applied to n-D subsets of data (in the prestack or migrated domain), obtained from the original 5-D prestack volume, n≤5. Usually picking is performed manually or semi-automatically on 2-D sections, for 3-D data the overall horizons are obtained by interpolating (few) 2-D interpretations. However, this approach cannot be considered as an efficient one as each estimate is carried out independently on each subset with no reference to the overall dataset.

Here it is proposed an automatic horizon picking (HP) method as a tool to support the manual interpretation that operates simultaneously on the overall n-D dataset. The HP algorithm has been originally proposed for 2-D volumes (for GPR applications, see Spagnolini and Rampa, 1999), then extended to 3-D data volumes (Bienati and Spagnolini, 1998, and Nicoli, 1997-98), and recently it has been extended to handle irregularly sampled data for n-D dataset (Bienati et al., 1999). The n-D data volume

$$s(\mathbf{x},t)=\sum_{k=1}^{L(\mathbf{x})} a_k(\mathbf{x})\,w(t-\tau_k(\mathbf{x}))+n(\mathbf{x},t)$$

is as a combination of $L(\mathbf{x})$ reflections, each characterized by the waveform $w(t)$, the amplitude $a_k(\mathbf{x})$ and the delay (or depth for migrated data) $\tau_k(\mathbf{x})$; t denotes the time (or depth) and $\mathbf{x}=(x_1, x_2, \ldots, x_{n-1})$ is the (n-1)-D space coordinates; $n(\mathbf{x},t)$ is the structured noise given by the combination of the interfering events. HP is used to estimate the traveltime (or depth) $\tau_k(\mathbf{x})$ according to a continuity constraint embedded into the HP algorithm. Since the automatic HP has to be used to integrate and extrapolate the manual interpretations, it needs to be driven on the specific target area by the interpreter. The interpreter can place few seed picks on the horizons (e.g., a manual interpretation on one or more 2-D slices of the n-D volume can be used as initialization as well). These seeds are then used by the HP algorithm as starting points, horizons tracking will be exploited by letting the seed picks grow under statistical constraints (e.g., the horizon is modelled as a Markov random field, see Spagnolini and Rampa, 1999, and Nicoli, 1997-98).

Even if the HP algorithm is based on the local continuity of the horizons, it can take advantage of the higher dimensionality of the pre-stack data mostly in areas of faults, diffracting and crossing horizons, low SNR or sparse sampling; in these areas, the errors are usually limited. Often HP can be much easier performed in the depth domain after migration (if needed); the results are then converted into time domain by demigration (Bienati et al., 1999). For a continuous and locally smooth horizon the estimation can be easily performed by automatic algorithms, however, the HP techniques here considered are also able to handle discontinuities (e.g., faults). If the horizon is connected in the n-D volume the estimation is performed along the largest continuity paths of the horizon that go around the discontinuous areas (Bienati et al., 1999). If the target horizon is the union of disjointed horizons, the interpreter can drive the algorithm by placing one seed pick on each surface (see Fig. 1-2). However, when the association between time-horizon and depth-horizon is not clearly defined, the HP method becomes less reliable. In this case, the interaction with the interpreter becomes important, as the HP can be easily made interpretation-driven.

In summary, the HP algorithm can be used either to estimate the target horizons in the prestack data or to refine the interpretation by exploiting the full dimensionality of the pre-stack data.

EXAMPLE

Figure 1-2 show an example of discontinuous horizon picking. HP is applied to a 3-D prestack volume (for visualization the data have been nmo corrected), from a 2-D acquisition. Since the target consists of four main faults, or equivalently five disjointed horizons, HP is performed by placing one seed point on each surface. Since the global optimization of the HP algorithm is decomposed into the combination of several local optimizations (Bienati et al., 1999), the HP is independent on the location of the seed on the surface.

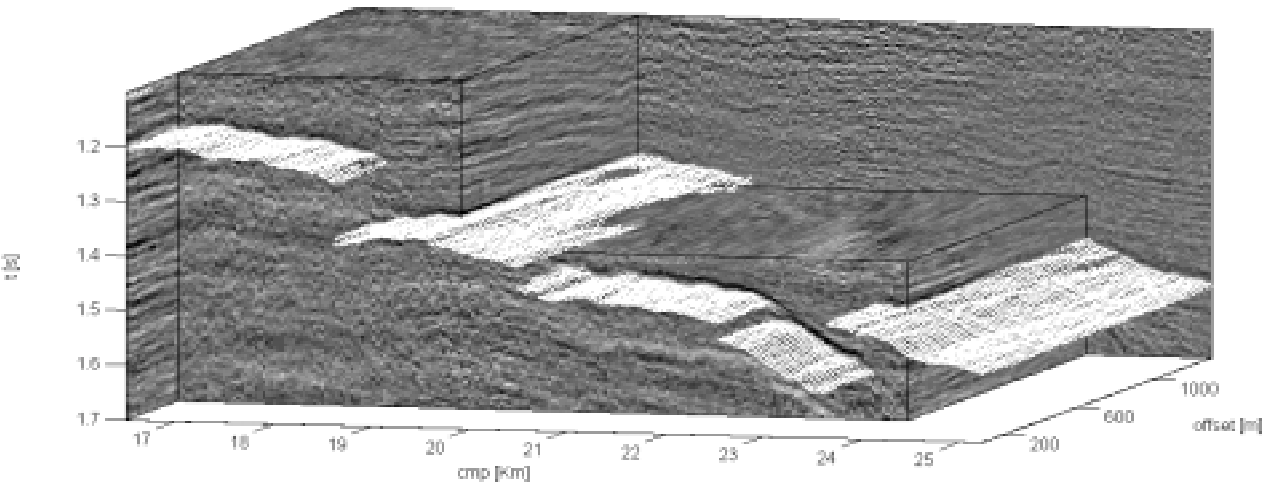

Figure 1 – HP for 2-D seismic surveys: picking of a multifaulted horizon on a 3-D prestack data volume.

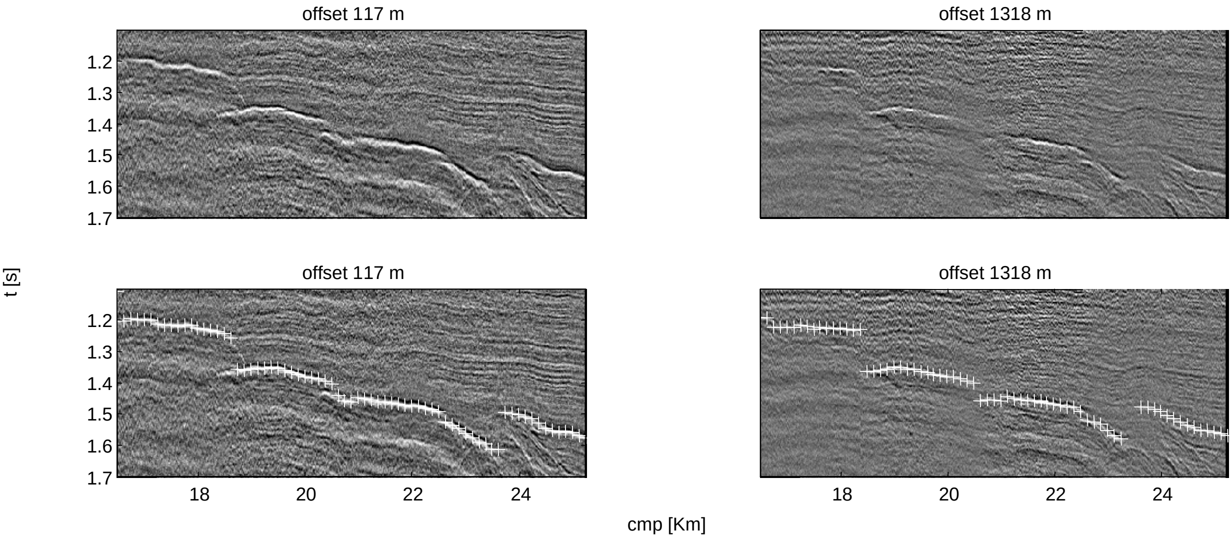

Figure 2 – Detailed view (offset slices) of 3-D data volume in fig.1: data (upper part) and estimated horizons (lower part).

ACKNOWLEDGEMENTS

We would like to thank ENI-AGIP Division for providing the field dataset shown here.

REFERENCES

N. Bienati, U. Spagnolini, 1998, "Traveltime picking in 3-D data volumes", *Ext.Abstract 60th EAGE Meeting, Leipzig.*

M. Nicoli, 1997-98, "Rivelazione e inseguimento di orizzonti multipli nella sismica a riflessione*", Thesis as Dottore in Ingegneria delle Telecomunicazioni (in italian).*

U. Spagnolini, V. Rampa,1999, "Multitarget detection/tracking for monostatic Ground Penetrating Radar", *IEEE Trans. Geosci. Remote Sensing, vol.37, n.1, pp.383-394.*

N. Bienati, M. Nicoli, U. Spagnolini, 1999, "Automatic horizon picking techniques for multidimensional data", *Ext. Abstract 61st EAGE Meeting, Helsinki.*