SBGf08799

Migration and Modeling of Pick Data with Traveltimes

Cole C. Harris and Michael O. Marcoux

Veritas DGC, Inc., USA

ABSTRACT

Kirchhoff migration and modeling algorithms are integral methods in which the dominant contribution to the integral is from the stationary phase regions of the operator-mapped input data. We have developed an analogy to such Kirchhoff methods for application to event picks derived from seismic data. In contrast to the Kirchhoff algorithm, our method explicitly detects the stationary phase regions in the operator-mapped input pick dataset and associates with each an output pick. Unlike map-migration type algorithms, this method does not require horizon dip information, or even that the picks be assembled into distinct horizons. Thus, relatively simple automated seismic data picking algorithms may be employed to generate the input pick dataset.
Two applications of these algorithms are depth model verification using reflection time pick migration and the generation of reflection time picks from time-migrated data for use in traveltime tomography.
Both migration and modeling algorithms have been verified on a pick dataset derived from a relatively complex model incorporating steep dips and non-smooth reflectors.

INTRODUCTION

A set of seismic horizon picks may be thought of as a purely kinematic description of the underlying seismic event. Even though amplitude information is lost, pick data algorithms paralleling those of traditional seismic data processing have been developed. An example of this is map migration by ray tracing. The motivation for the application of such techniques is their computational economy derived from the efficiency of the pick representation. We have developed pick data algorithms similar to the Kirchhoff methods routinely applied in seismic data processing. The technique may be described by comparison to a particular implementation of the well known Kirchhoff migration algorithm.

Kirchhoff migration may be broken down into a series of moveout, scale, and sum operations over the input data. In an typical output-oriented implementation, an input sample is scaled and moved-out according to the migration operator, and summed into the output sample. This sequence is then repeated for each sample in the output trace. An equivalent implementation would first moveout and scale all of the input data within the output trace aperture, forming what we call a 'migration aperture projection gather' or MAP gather. The output trace would then be formed from the stack of this gather. The dominant contribution to this stack is from the stationary phase regions of the MAP gather. Our pick data algorithms incorporate two steps similar to the seismic data Kirchhoff implementation. These steps are discussed below.

OPERATOR MAPPING OF PICK DATA

We have previously reported on our analysis of seismic data MAP gathers (Harris et al., 1998). The following summarizes much of that work as it applies to pick data. Consider picks representing a single dipping reflection event as depicted in Figure 1. For an output surface location, surface to depth traveltimes are used to map all of these reflection time picks within the migration aperture to depth as shown in Figure 2. In this simple example, the correct output depth pick is the pick of maximum depth within this gather (Bickel, 1998). For more realistic pick datasets representing several reflection events, a more robust method of determining the depth of the output picks is required.

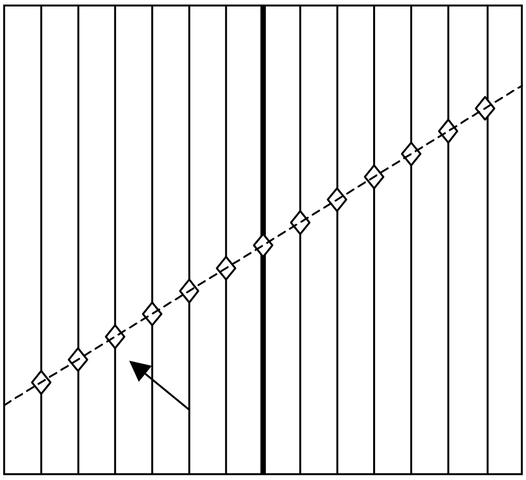

Figure 1 - Time picks from dipping seismic reflection event. The arrow indicates the pick that correctly migrates to the output surface location denoted by the dark trace.

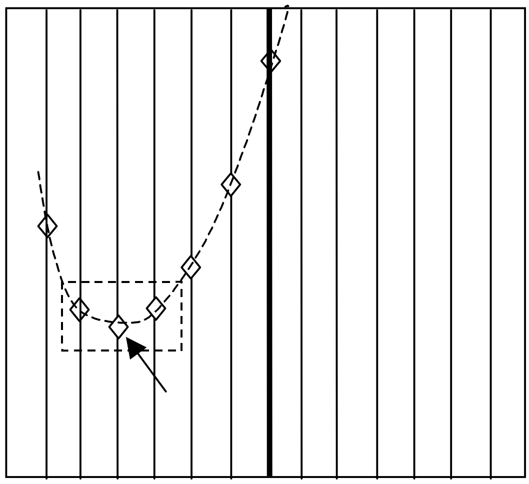

Figure 2 - Migration moveout has been applied to the picks in Fig. 1. Note that the deepest pick (arrow) is also in the region of highest lateral pick density (box).

IDENTIFICATION OF STATIONARY PHASE REGIONS

Within the collection of migration moved-out picks shown in Figure 2, the region of high lateral pick density may be interpreted as an area of stationary phase of the underlying seismic event in the MAP gather. Since the seismic migration output is dominated by the stationary phase regions in the MAP gather, an output pick is generated for each detected high pick density zone. While a robust definition of relative pick density is still under investigation, we have found that a simple count of picks falling within a small 3d window is an adequate indicator for the tests we have conducted.

PICK MODELING

The same algorithm may be used to model reflection times from a collection of picks generated from a seismic depth section. Only the direction of the mapping is reversed. Thus, unlike map migration which is normally implemented as an inversion procedure, both pick migration and modeling are achieved by the same forward processes in this method.

APPLICATIONS

In addition to the usual applications of map migration, a prestack version of this migration algorithm may prove useful in depth model updating processing sequences, or as a tool for depth model verification. Another possibility is the direct detection of aperture windows for migration input in MITAS as described by Harris, et. al. (1998).

The modeling routine is expected to be useful in the generation of reflection time picks for traveltime tomography. In this application, picks from prestack time-migrated data would form the input dataset. It is thought that, since migrated data is better organized than unmigrated data, these picks will be more reliable than picks from the original seismic reflection data Thus, the modeled pick dataset should contribute to the stability of the tomograpy inversion procedure.

SYNTHETIC EXAMPLE

We have applied this technique to a 2D dataset generated from a vertical slice through a 3D salt dome depth model. The input pick dataset shown in Figure 3 was produced by an automatic picking routine. These picks were modeled with a constant velocity (Figure 4) and compared to the corresponding seismic reflection data (Figure 5). The results are quite similar though some differences exist. The steepest portion of the salt flanks were not well sampled in the input pick dataset, and thus are not recovered in the modeling result.

Other differences are attributed to the absence of amplitude and phase information in the pick representation resulting in extraneous diffractions, and incorrect identification of high pick density regions.

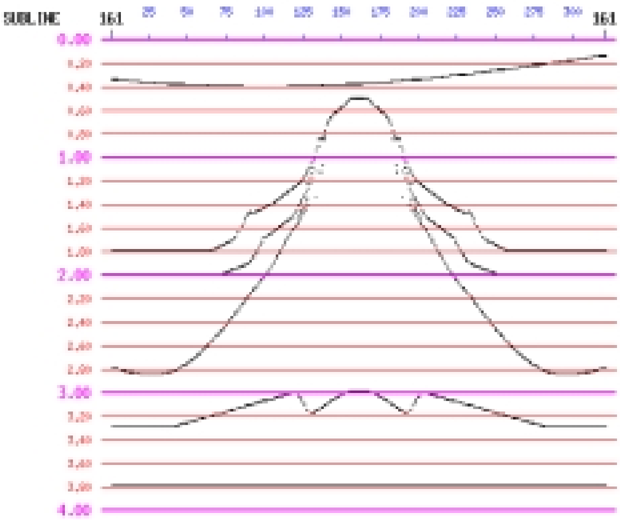

Figure 3 - Depth picks generated from vertical slice through 3D salt dome model.

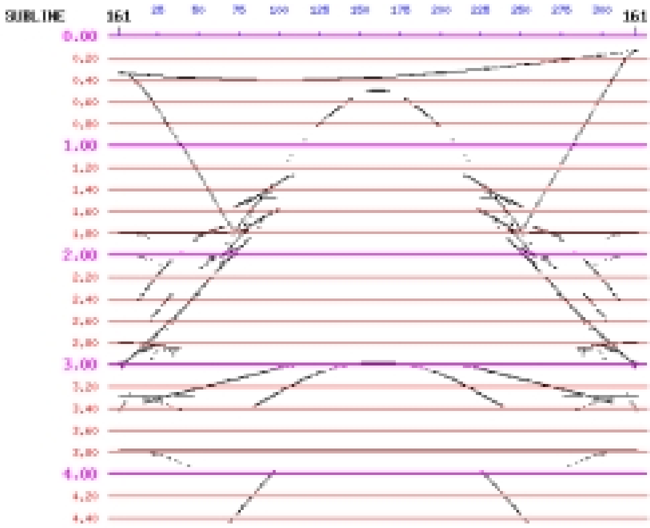

Figure 4 - Reflection time picks generated by modeling picks in Fig. 3.

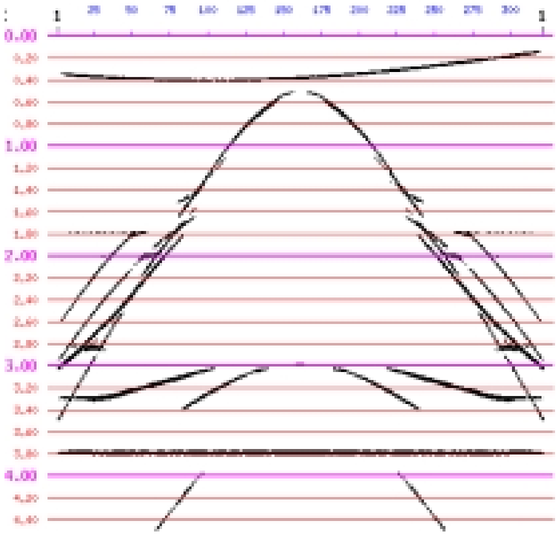

Figure 5. Phase shift diffraction of original seismic data.

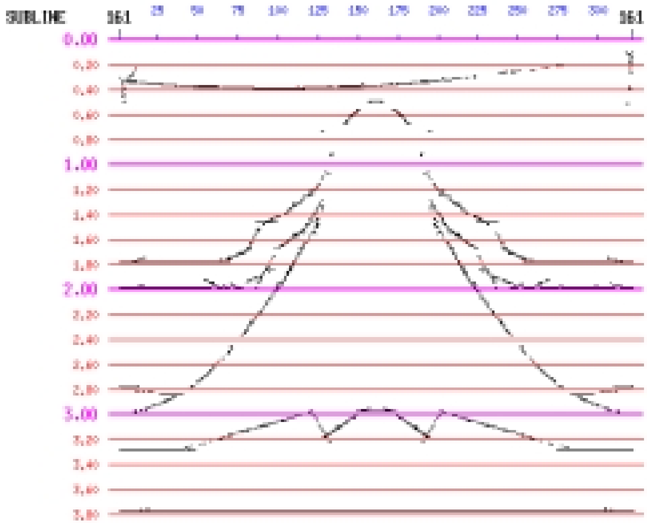

Figure 6. Pick migration of reflection time picks in Fig. 4.

To examine the invertability of the technique, the modeled pick dataset was migrated (Figure 6). The image is in good agreement with the original depth pick dataset (Figure 3). The discrepancies are believed to be associated with the difficulty of identifying regions of high pick density.

DISCUSSION

We have presented a method of pick modeling and migration without explicit use of ray tracing. This was accomplished by propagating either reflection or reflector surfaces using the stationary phase principle and the traveltimes typically used in Kirchhoff algorithms. The technique has been successfully applied to a 2D pick dataset generated from a salt dome reflector model. Examples of 3D pick imaging are in preparation. Application in regions of noisy pick data or several complex picked events will likely require investigation into alternative detection schemes for pick density.

References

Bickel, S., 1998, The maximum depth principle as a dual to Fermat's minimum time principle: 60th Mtg. Eur. Assoc. Expl Geophys., Extended Abstracts 1-55.

Harris, C., Marcoux, M. and Bickel, S., 1998, Aperture selection to improve Kirchhoff depth imaging using the maximum depth principle: 60th Mtg. Eur. Assoc. Expl. Geophys., Extended Abstracts 1-56.

Harris, C. Marcoux, M. and Bickel, S., 1998, MITAS, migration input trace aperture selection: 68th Annual Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts,1373-1376

ACKNOWLEDGMENTS

We would like to thank Veritas DGC, Inc. for permission to publish this work.