Reflection travel time tomography using blocky parameterization

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Abstract

Initial velocity model close to real velocity structure of the subsurface governs the quality of image of prestack depth migration. Geophysicists employ velocity estimation tools such as velocity analysis (curvature method, coherency inversion), tomography and waveform inversion.

We present a reflection tomography that parameterizes the subsurface into the movable blocks. By interpreting the depth-migrated section or stacked section, we can design an initial constant velocity model having only impedance boundaries. We use shooting- raytracing method that allows us to calculate the Jacobian-matrix efficiently.

Introduction

Seismic tomography can be classified into three groups.: transmission, refraction and reflection tomography. Unlike transmission and refraction tomography, reflection tomography needs to define reflector boundaries and pick their travel times from a stacked section or depth-migrated images. In the way of parameterizing subsurface velocity model, we can divide seismic tomography into a blocky and a cell tomography. In cell tomography, the velocity model is constructed by small cells(Hampson and Russel, 1984) by minimizing the resudual between the measured travle time and the initial model response. Blocky parameterization subdivides velocity model into movable blocks to fit the velocity model(Shin, 1988).

In this study, we exploit blocky tomography to obtain close initial velocity model to the real velocity structure of the subsurface. Blocky tomography has an advantage of using constant homogeneous velocity model as an initial velocity model. The number of unknown of blocky tomography is usually less than a thousand, depending upon the complexity of the geological model, so that we can update the velocity fast using this scheme.

By interpreting the depth-migrated section, we chose a constant initial velocity model that has only impedance boundaries. The velocities and the interfaces of each block are updated iteratively by using a classical Gauss-Newton method. In the case of simultaneous travel time inversion for both velocity and interface, the difference of scale between the Jacobian matrix of velocity perturbation and Jacobian matrix of interface is so big that it can cause the instability of Hessian matrix, thereby employing a logarithmic change of variables(Madden, 1972) to make Jacobian matrix scale free. By showing numerical examples, we demonstrate that our blocky tomography travel time inversion can be a good candidate for the estimation of initial velocity for prestack depth migration.

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Numerical examples

Figure 1 shows the results of inversion for both velocity and interface travel time inversion. Figure 1(a) shows the true velocity model and Figure 1(b) shows the initial velocity model. . The velocities of each block in initial model are fixed as constant velocity (1500m/s). Figure 1(c) is a finally updated model and the difference between true and updated model is plotted in Figure 1(d).

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Figure 2 shows the results of inversion for 5-layered velocity model of Figure 2(a) using picked travel time. The velocities of each block in initial model are fixed as constant velocity (1500m/s). We picked the travel time from the seismic data of model in Figure 2(a) using the software, Geoframe of Geoquest. In Figure 2(b), we post the interpreted reflectors superimposed on the common offset gather and Figure 2(c) shows the travel time contour of reflector A. Figure 2(d) shows the true velocity and the updated velocity using our algorithm for the model in Figure 2(d).

Conclusion & Future study

Our numerical tomography examples shows a feasibility of adapting a reflection tomography to the picked travel time of real data. We successfully inverted the travel times by changing the velocity of blocks and by moving the coordinates of the interface separating the blocks. In the way of blocky parameterization, we could reduce the number of unknowns amenable to use Hessians to regularize the gradient vector.

Future study is to practice our tomography algorithm to real data set for better estimation of initial velocity model of migration.

Acknowledgements

The authors would like to thank for the financial supports of the Brain Korea 21 Project and the National Research Laboratory project of Ministry of Science and Technology, and also thank to GeoQuest for the use of GeoFrame software.

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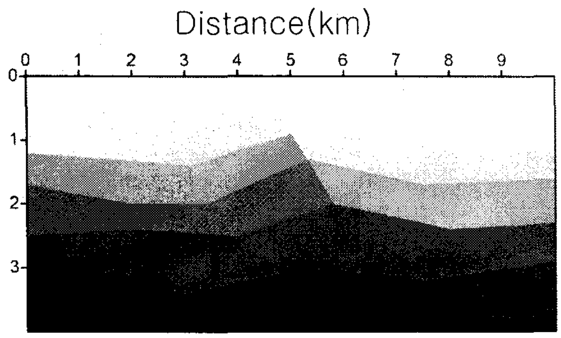

Fig. 1(a) True velocity model

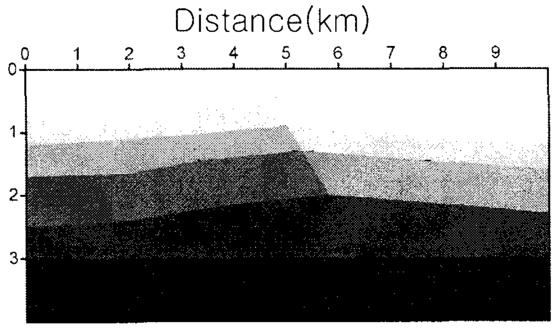

Fig. 1(b) Initial velocity model

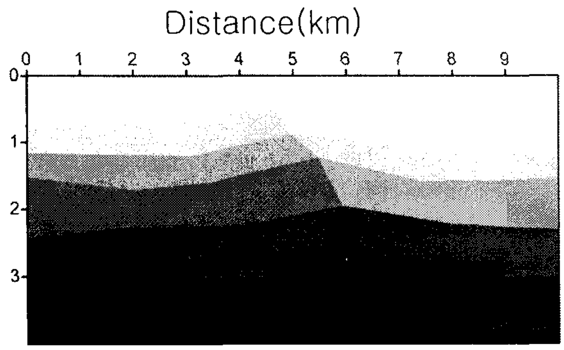

Fig. 1(c) Updated velocity model

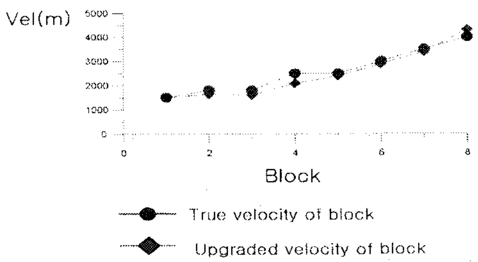

Fig. 1(d) Velocities of true and updated model

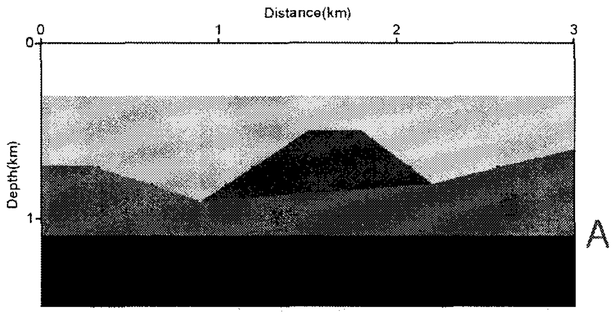

Fig. 2(a) True velocity model

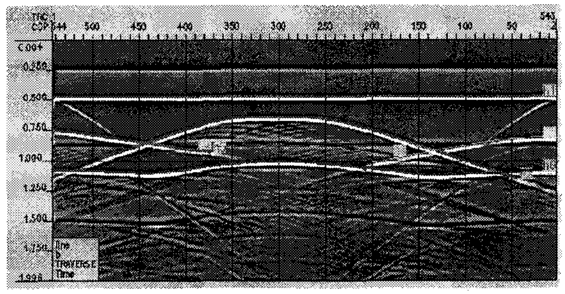

Fig. 2(b) Interpreted reflectors

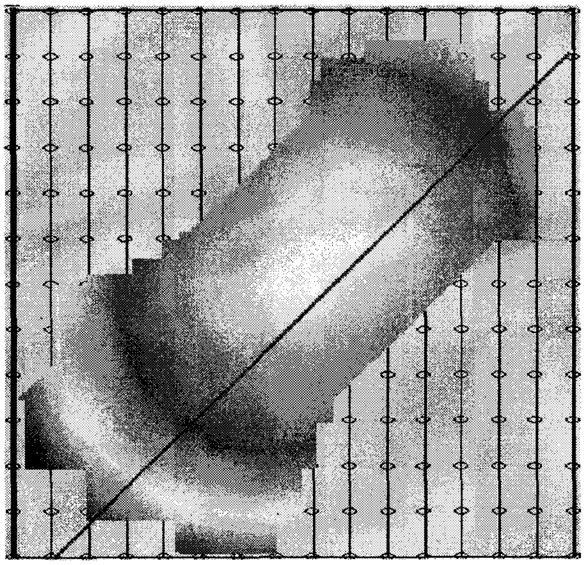

Fig. 2(c) 3-D contour of interpreted travel time of reflector A

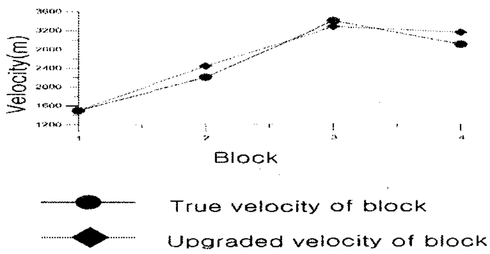

Fig. 2(d) Velocities of true and updated model