Interpolation of multi-line 2-D seismic data

Naoshi AOKI*, Kazuya SHIRAISHI**,
Masato MINEGISHI*, Toshifumi MATSUOKA**

*Japan Petroleum Exploration Co.,Ltd., Chiba, Japan
**Kyoto University, Kyoto, Japan

Abstract

3-D seismic survey is recognized as a very powerful exploration tool and the usage is widely made to obtain clearer subsurface images. However, there is the case in which the acquisition of 3-D seismic data is not allowed economically or in exploration strategy. In such a case only existing 2-D data give the subsurface information. However, the interpretation of multi-line 2-D seismic data is always ambiguous under the complex geological structure. The main reason is that the sideswipe reflections are not separated on single 2-D seismic data. The only way to improve the interpretation accuracy is that the sideswipe energy contained in multi-line 2-D data set is located in the correct reflection position and shapes the reflector image by means of 3-D pre-stack depth migration (PSDM).

Our final goal of the study is to obtain a 3-D subsurface image from multi-line 2-D seismic data by means of 3-D PSDM. The critical issue of the approach is that the subsurface spatial sampling is too sparse to obtain a meaningful PSDM image. Therefore, the elaborated interpretation technique is necessary to compensate the lack of spatial sampling

In this paper we will discuss an interpolation technique to produce a pseudo 3-D data set from sparse multi-line 2-D data using t-x-y domain operator.

1 Introduction

3-D seismic survey is a very powerful exploration technique, but it is not easy to use because of survey cost problems. To overcome this problem we investigated an interpolation methodology using 2-D seismic data. Our study proposes a method to produce pseudo 3-D data from existing multi-line 2-D seismic data. 3-D structure affects 2-D images. Sideswipes often lead wrong interpretation. Conventional 2-D imaging could not separate the energy. To improve the interpretation accuracy, the enegy must be removed. We are trying to produce 3-D image volume by means of 3-D pre-stack depth

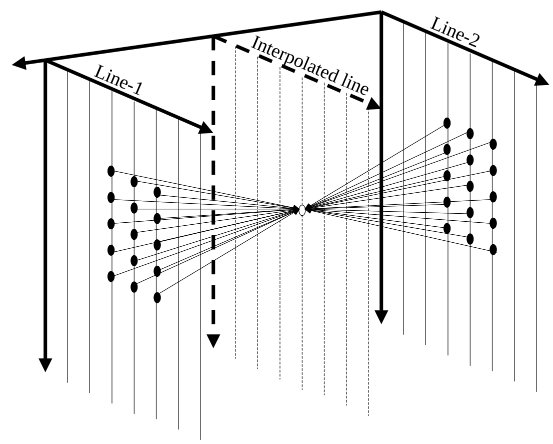

Fig. 1: Interpolated data set is obtained by convolving weighting function f(t,x,y) and sampled data set.

migration (PSDM). The critical issue of the approach is that the subsurface spatial sampling is too sparse. The interpolated data set helps 3-D imaging.

There are known some interpolation techniques in f-x domain (Spitz, 1991), in f-x-y domain (Wang, 2002), and in f-k domain (Schonewille, 2000). However, they require 3-D Fourier transform of data set and it may be cost concerning.

In this paper, we will discuss the interpolation technique using t-x-y domain operator. It is hard to design an interpolation operator in shot domain, because seismic events have several apparent velocities. In this study, common offset gathers domain is adopted in interpolation, it makes it easy to determine the t-x-y domain operator considering the influence of subsurface structures. Synthetic examples give us good interpolated results by proposed method.

2 Methodology

In this section we discuss a method of interpolation of the seismic data from the observed data set. The interpolated data is obtained by convolving a weighting-function $f(t,x,y)$ defined in t-x-y domain by sampled data (Fig.1) (weighting summation). This weighting-function is defined by the following formula as $f(t,x,y)$.

$$f(t,x,y) = \frac{1}{2\pi x_0 y_0} \exp\left(-\frac{x^2}{x_0^2} - \frac{y^2}{y_0^2}\right) \cdot \frac{\sin(2\pi f_0(t + c_1 x + c_2 y))}{2\pi f_0(t + c_1 x + c_2 y)} \qquad (1)$$

In this equation, both x and y are distances between receiver points of sampled data and interpolated data position, and t means time of sampling. There are five parameters in the equation (1), f_0 is the maximum frequency of seismic data, x_0 and y_0 define the influenced area of weighting-function, c_1 and c_2 are determined from interpreted dip in x and y domain. We assume that operator shape is expressed as a sinc function band-limited between $-f_0$ and f_0 in time domain and reflection boundaries expand in an area defined as the gaussian distribution that has standard deviations x_0 and y_0. In addition, the structural parameters, c_1 and c_2 that means structual dip of x and y domain (dt/dx,dt/dy).

The weighting-function can be changed in time and space if the five parameters are given as functions of time and space. We use common offset gathers in spite of shot gathers. The reason is to be able to use structural interpretation directly in determining the weighting function. At an arbitrary point, the interpolated trace is obtained by summing of calculating the weighting-function for every input traces.

3 Synthetic example

We applied this interpolation method to a synthetic data set. The data set is generated from a dipping boundary model. The boundary has both in-line and cross-line dip those are $-5°$ and $5°$, and the depth at $(0,0)$ is 1000m. The P-wave velocity of upper medium is 2000m/s and the lower medium is 1800m/s (Fig.2). We choosed this velocity structure since there does not exist over critical reflections.

Fig.3 shows location of sources and receivers of the synthetic data and the interpolated data. Line-s1 and Line-s2 show the pseudo survey lines,which have 150m shot and receiver offset and $5°$ of feathering. Line-1, 2 and 3 show interpolated lines. The distance between lines is shortened from 500m to 125m. Fig.4 shows synthetic data on Line-s1 and Line-s2, there are 32shots$\times$2lines data. The sampling interval time is 1msec and a wavelet is Ricker wavelet whose peak frequency is 100Hz.

In Fig.5, 3 lines (Line-1, Line-2 and Line-3) are interpolated from above 2 lines. This example shows that the proposed method can produce a reasonable pseudo line data. The future work is to consider time- and space-variant operator for complex structure.

4 Conclusion

In this study, it is suggested that interpolation method using t-x-y operator to produce pseudo seismic traces from existing multi-line 2-D seismic data. In simple synthetic example, this method shows good results. We will apply this method more complex case or/and field data and concider more detail of this method in future.

We believe this interpolation method helps us to acquire better 3-D image volume from multi-line 2-D seismic data by means of 3-D PSDM.

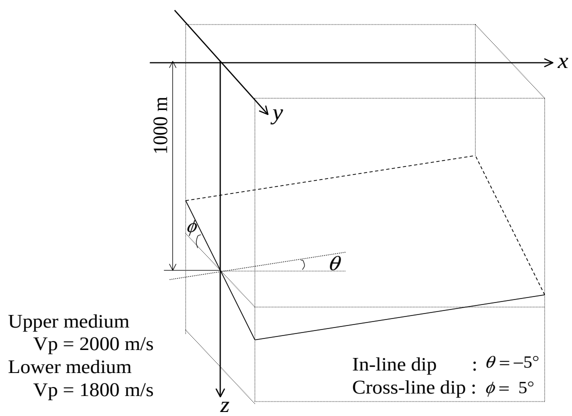

Fig. 2: Synthetic example: one diped boundary model. P-wave velocity of the upper medium is 2000m/s and the medium is 1800m/s. In-line dip is $-5°$ and cross-line dip is $5°$

References

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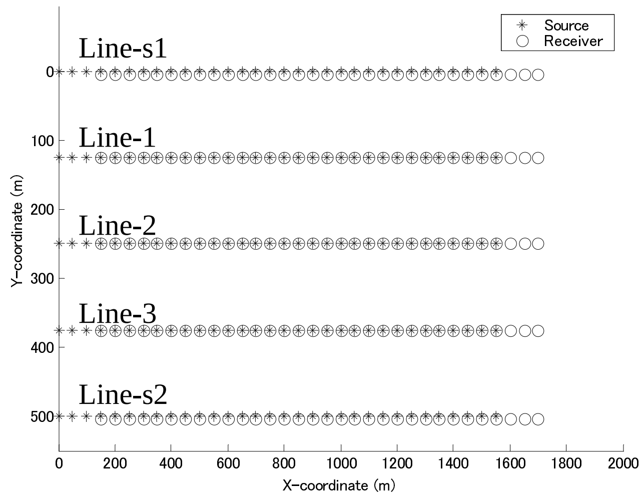

Fig. 3: Line-s1 and Line-s2 are surveyed lines that have sampled data, and Line-1, Line-2 and Line-3 are interpolated lines.

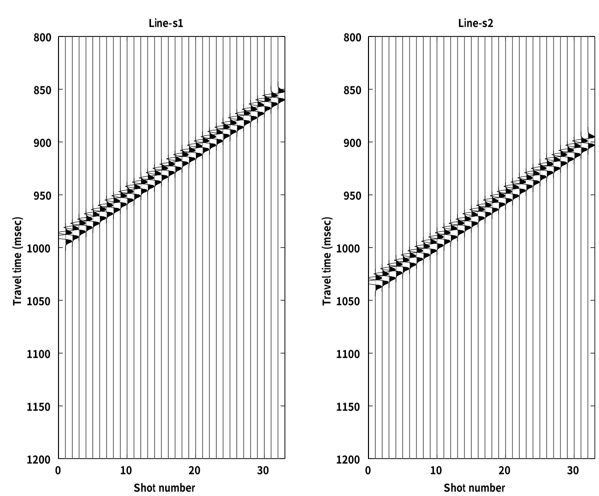

Fig. 4: Synthetic data on Line-s1 and Line-s2.

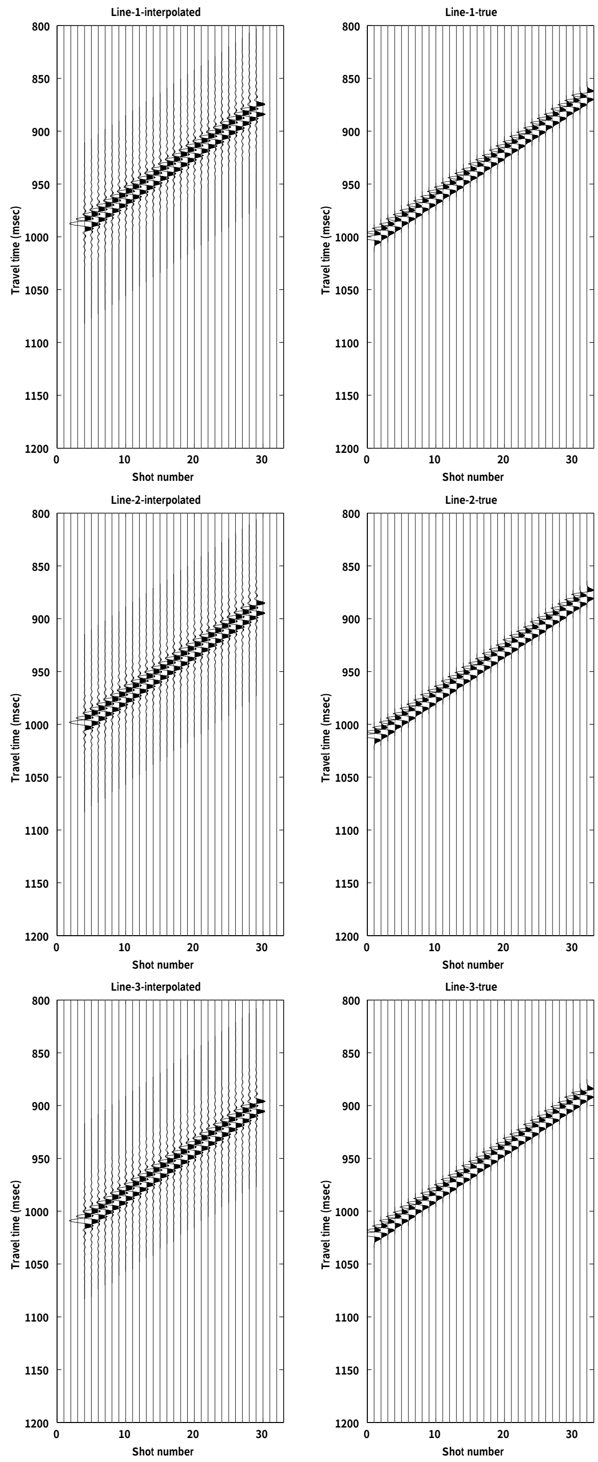

Fig. 5: Comparison of interpolatd data and true data on Line-1, Line-2 and Line-3.