**Pseudo 3D seismic using biharmonic spline interpolation**

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**Abstract.** Pseudo three dimensional (3D) seismic has been carried out to real seismic dataset using biharmonic spline interpolation. The dataset contains 11 two dimensional (2D) seismic lines with two-millisecond sampling rates and 2000 millisecond record length. Biharmonic spline interpolation was performed for each time sample using the gridding interval of 25 x 25 meter. The resulted interpolation for each time sample was combined to generate three-dimension matrix that called as pseudo-3D seismic. The results of pseudo-3D seismic data clearly showed the structural geological features, compared to 2D seismic data. The result can minimize the uncertainty of the subsurface interpretation and reduce the exploration risk.

**Keywords:** Pseudo 3D seismic, biharmonic spline interpolation, 2D seismic.

1. **Introduction**

Three dimensional (3D) seismic data is one of the important in hydrocarbon exploration. 3D seismic data can be used for detailed subsurface interpretation. In principle, 3D seismic data more powerful compared to 2D seismic, which is the 3D data has less uncertainty in imaging the condition of earth’s subsurface in which the resulted data has more accuracy and higher resolution than the 2D data. However, 3D seismic data is very expensive. An oil company must invest a high cost to get 3D seismic data. Any companies want 3D seismic data, but they are constrained by cost, and the company cannot get the 3D data. Therefore, this paper aims to get pseudo 3D seismic data with 2D data. Basically, pseudo 3D seismic data can be obtained by converting 2D data with interpolation which this research used biharmonic spline interpolation to do it [1].

2. **Methodology**

Biharmonic spline interpolation was first discovered by sandwells [1]. Biharmonic spline interpolation can be used to find the minimum curvature from the distribution of irregular data points by using a green function. Biharmonic spline interpolation can be used to find the minimum curvature from the distribution of irregular data points by using a green function [1, 2]. The interpolation curve is a linear combination of Green functions centered at each data point. This method is more flexible than the spline method since both slopes and values can be used to find a surface [1]. The benefit of this method is it is easy to be used for interpolation problems in three or more dimensions. In three dimensions, it corresponds to multiquadric interpolation [3, 4]. In other words, the biharmonic spline interpolation method is simpler than a cubic spline.
The obstacle in applying this method is to get a biharmonic function that clears the \( N \). This challenge was already solved by Draftsmen et al. by adding weights to an elastic beam or spline and arranging the weights so that the spline passing the data points [1]. The forces appoint on the spline by each weight kept it arced. For small displacements, the spline has zero fourth derivative except at the weights. The point force Green function for the spline meets the biharmonic equation.

\[
\frac{d^4 \Phi}{dx^4} = 6\delta(x)
\]  

(1)

The particular solution to equation 1 is:

\[
\Phi(x) = |x|^3
\]

(2)

when green functions used to interpolate \( N \) data points, \( w_i \), located at \( x_i \),

\[
\frac{d^4 w}{dx^4} = \sum_{j=1}^{N} 6\alpha_j \delta(x - x_j)
\]

(3)

\[
w(x_i) = w_i
\]

(4)

The appropriate solution to equation 3 and equation 4 is a linear combination of point force Green functions centered at each data point. The homogeneous solution is not used.

\[
w(x) = \sum_{j=1}^{N} \alpha_j |x - x_j|^3
\]

(5)

The strength of each point force, \( \alpha_j \), is found by solving the linear system,

\[
w_i = \sum_{j=1}^{N} \alpha_j |x_i - x_j|^3
\]

(6)

If slope, \( S_i \), is used rare than value, then \( \alpha_i \) are determined by solving with linear system,

\[
s_i = 3 \sum_{j=1}^{N} \alpha_j |x_i - x_j| (x_i - x_j)
\]

(7)

where \( \delta \) is biharmonic operator, \( N \) is a number of data points, \( \alpha_i \) is point force, \( x_i \) is a data point, \( W_i \) is the weight of data point \( i \), \( W_x \) is biharmonic function, and \( S_i \) is the slope of the biharmonic curve [1, 5].

3. Results and discussion
Data that used in this research were in the form of 2D seismic data. 2D seismic data contains only inline coordinates, 11 seismic lines, and thickness of 0–2000 ms. Pseudo 3D seismic data is obtained by time
slice. Figure 1 shown the real coordinate of seismic data. Result of the seismic line is represented of easting coordinate (x) and northing coordinate (y). The unit of coordinate is meters from the axis of some horizontal datum. Then the seismic line is rotated (13.94°) so that the seismic path becomes horizontal. The purpose of the rotation is interpolation according to the seismic path. The results of the rotation can be seen in figure 2.

The binning size that was used in this research is (25 m x 25 m). The purpose of the data grid is that the interpolation results obtained are better and more accurate. If the grid data gets closer, the interpolation will better. We used the binning size (25 m x 25 m) because the grid data is enough to clearly describe the features of the geologic structure, but if you want to get a higher level of resolution, the grid data must be smaller. The result of grid data (25 m x 25 m) can be shown in figure 3.

Figure 1. The real coordinate of seismic data.

Figure 2. Rotated coordinate (13.94°) to get a seismic path becomes horizontal.

Figure 3. Comparison of rotated coordinate and grid data (25 m x 25 m).
Figure 4 shown inline direction results of interpolation biharmonic spline. In figure 4, there is a pinch out the geological character and clearly visible geological structure in the form of continuous folds. But, results of inline direction cannot be used to determine pseudo 3D seismic data, because to get pseudo 3D seismic data we have to do time slice. Figure 5 shown xline direction, and the results of xline direction are not good. Xline coordinate (time 1400 ms) describes a geological structure that looks like a ladder, which should be continuous. It can occur because the data in this research are only 2D data in the inline direction, so the result of interpolation xline direction is not good. It could be a weakness of pseudo 3D seismic data.

To determine the quality of the pseudo-3D seismic processing, time slice was carried out. Figure 6 shows the results of the time slice at 882 milliseconds. It can be explained that the quality of inline
is good, but xline direction is not good. In another word the quality of time slice in the horizontal
direction is good, but the lateral direction is not good. Grey color represents no result in interpolation, it
is because there was not data in this area. Moreover, figure 7 shows a comparison of inline, xline, and
time slice (882 ms) which are displayed in 3 dimensions.
Figure 7 is only an example used at 882 ms time slice. Based on the results, we can describe the
geological structure in the direction of inline, xline, and at time slice 882 ms. Moreover, we can also
know the seismic picture at different time slices, so we can find out the zone with interest based on the
time slice from 2D seismic data.

4. Conclusion
Pseudo 3D seismic data resulted from a time slice of 2D seismic data. It can be used by biharmonic
spline interpolation. Based on the results, the geologic structure features are clearly shown. We can see
in figure 4, the fold structure appearance is clear especially in the inline coordinate, but on the xline
coordinate (figure 5), the result obtained is poor. Pseudo 3D seismic results can be better if we add xline
direction data. All proceeds of pseudo-3D seismic have been able to produce 3D seismic cube in SGY
format which ready for processing or interpretation. The result of this paper is the initial stage of seismic
data processing.

References
[1] Sandwell D T 1987 Geophys. Res. Lett. 14 139-42
[2] de Boor C 1962 J. Math. Phys. 41 212-8
[3] Hardy R L 1971 J. Geophys. Res. 76 1905-15
[4] Hardy R L and Nelson S A 1986 Geophys. Res. Lett. 13 18-21
[5] Feliciano-Cruz L I and Ortiz-Rivera E I 2012 IEEE Photovoltaic Specialists Conference 2012
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