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Analysis of different interpolation methods for uphole data using Surfer software

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Summary

An attempt has been made to understand the different interpolation techniques using SURFER software. Uphole data at 1000m apart have been interpolated with four different methods for velocity, line, picket and reduced depth. Around 25% of the data sets were deleted randomly from the actual data sets to see the difference between interpolated data sets and the true data sets. While doing this, anisotropic factors were varied for different methods to see the quantum of difference between interpolated data sets and the true data sets. Kriging method of interpolation is found to give better result for present data set.

***Keywords**: Interpolation, Uphole & Kriging.*

Introduction

Seismic data acquisition is very important aspect of the hydrocarbon exploration. Obtaining a good quality seismic data requires proper receiver and source coupling and accurate static corrections.

Very often Uphole data are acquired with regular spatial distribution to estimate velocity and depth information of near surface layers. Sometimes spacing between these discrete upholes varies in both the directions i.e. in inline and cross-line due to logistics etc. Typically the spacing varies from half a kilometer to kilometer depending upon the logistics of the area. One-dimensional velocity model from each uphole is used to build two dimensional velocity model by using interpolation. These models are very important for accurate static corrections at any required location for source and receivers and to provide the optimum depth for shot holes for seismic data acquisition.

Interpolation refers to the process of estimation of unknown data points at desired locations using the nearby known data points. In most of the cases we would like to model a feature as a continuous field or surface, but we have values at discrete points. Hence it becomes necessary to interpolate the data points to get the information for intermediate points.

In the present study an attempt has been made to investigate the effect of four interpolation methods using Surfer software for uphole data sets in the study area.

Efforts have been made to find out the method which gives minimum misfit between the actual and the interpolated data sets by minimizing the root mean square error or RMS error.

The uphole data from the Akholjuni area falling in TarapurCambay block of the cambay basin is used for the present study. The area under study is having an influence of both the fluvial and marine environment on the near surface geology.

Data Analysis

Data from sixteen upholes have been taken along a crossline passing through north-south direction. The southern part of the area is near to the coast and elevation varies from 4m to 14 m as we move from south to north.

The total 192 upholes were conducted in the study area out of which 16 upholes were used to make one crossline passing through north-south direction as shown in the figure 2(a). The figure 2(a) shows the red stars as the location of the each upholes in the area of investigation.

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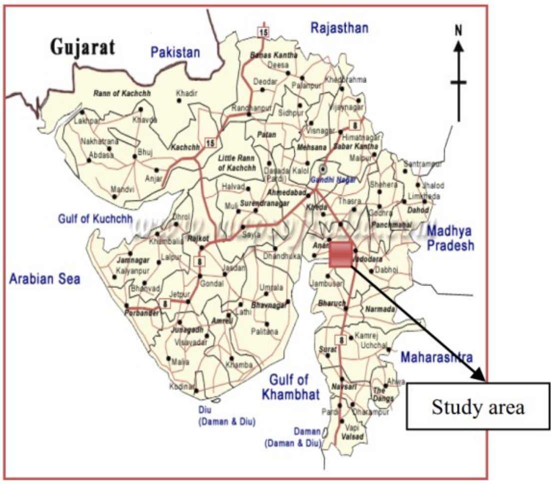

Figure 1. Location of the Study area

The black line in north-south direction is used to mark the location of those upholes which are used in the present study.

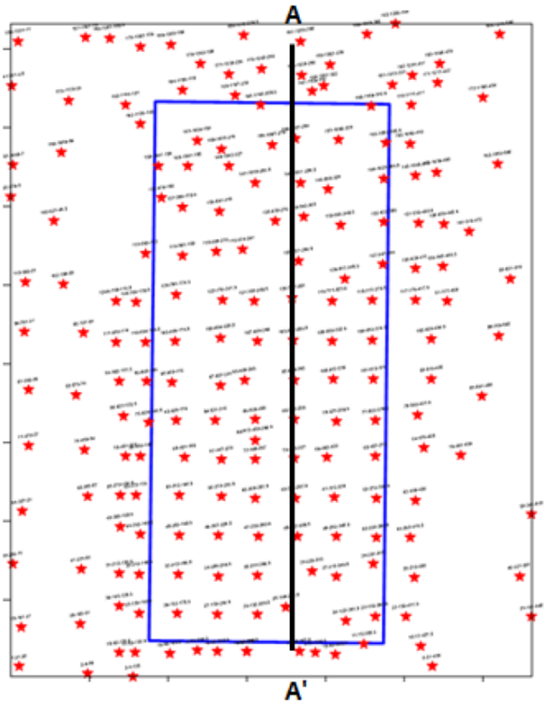

Figure 2(a). Uphole grid (1km x 1km) showing AA' line along which, upholes are used in the present study.

The schematic is shown in figure2(b) for the crossline uphole plots along crossline AA' used in the present study. The blue marked ovals at different positions of each uphole represents the random locations from where the velocity values corresponding to depth have been removed. The typical uphole plot is actually a time-depth plot and the slope of the plot gives the velocity of the individual layer.

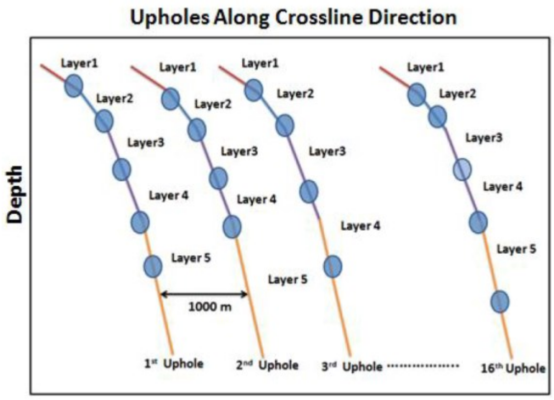

Figure 2(b). T-D plot of different upholes along part of crossline AA'

To study the effect of interpolation on our data sets, we have removed the data sets (velocity and depth corresponding to particular uphole). These data sets have been removed from all the sixteen upholes randomly corresponding to different depths as shown in figure 2(b). Originally there are 902 data points for all the sixteen upholes used in the study. We have removed 218 data values randomly from different layers at different depth from all the sixteen upholes. The remaining 684 data points have been used to study the four interpolation techniques using surfer.

SURFER is 3D surface mapping program, for transforming random data sets into continuous curved face contours using interpolation. Surfer uses twelve different methods for interpolating data sets. However in the present case, only four methods are used for interpolation to study the minimum misfit between the actual data sets and interpolated data sets and their dependence on varying degree of anisotropy.

Interpolation Techniques

The brief descriptions of four interpolation techniques under investigation are as follows:

Kriging Method

Inverse Distance to Power a Method

Minimum Surface Curvature Method

Radial Basis Function Method

Kriging Method

Named after a South African mining engineer D. G. Krige who developed the technique in 1963, attempts to more accurately predict ore reserves. Over the past several decades kriging has become a fundamental tool in the field of geostatistics. This method produces visually appealing maps from irregularly spaced data sets.

Inverse Distance to Power a Method

The Inverse Distance to a Power gridding method is a weighted average interpolator, and can be either an exact or a smoothing interpolator. With Inverse Distance to a Power, data is weighted during interpolation such that the influence of one point relative to another declines with distance from the grid node. Weight is assigned to data through the use of a weight power that controls how the weight factors drop off as distance from a grid node. One of the characteristics of Inverse Distance to a Power is the generation of „bull's-eyes" surrounding the position of observations within the gridded area. However, a smoothing parameter may be applied during interpolation in order to reduce the „bull's eye" effect.

Minimum Surface Curvature Method

The minimum surface curvature method was developed by Briggs Ian C. in 1974. He demonstrated that if the total curvature of a surface is minimized under the constraint that the surface honors the values at sampled locations. The principle of minimum total curvature provides a method of two-dimensional interpolation with reasonable maps of geophysical data (Briggs I. C, 1974).

However, Minimum Curvature is not an exact interpolator, Consequently source data is not always honored exactly. Minimum Curvature produces a grid by repeatedly applying an equation over the grid in an attempt to smooth the grid.

Radial Basis Function Method

Radial Basis Function interpolation is a diverse group of data interpolation methods. In terms of the ability to fit source data and to produce a smooth surface, the Multiquadric method is considered by many to be the best. All of the Radial Basis Function methods are exact interpolators, so they attempt to honor the source data.

Discussion

For the efficient data analysis, a query has been designed using MS access in such a way that each time when data has been interpolated, it will fetch the velocity data corresponding to a particular uphole and depth for which data have been initially removed. It has helped us to get the difference between actual data and estimated data very fast.

Data have been interpolated for every 10m in spatial direction and for every meter in depth. In doing so data sets were generated for varying anisotropic factor 1,2,4,6,8,10,12,16 and 20 corresponding to Kriging and Inverse method. If the direction and magnitude of anisotropy are known, they can be transferred to improve the modeling performance (Jeff Biosvert,2009). Anisotropy during gridding implies a preferred direction, or direction of higher or lower continuity between data points. Anisotropy is applied by specifying an anisotropy ratio i.e. is giving more weight to points located along one axis versus points located along another axis (ref. online surfer manual). These interpolation technique provide the anisotropic factor that incorporates the direction of continuity to improve upon the interpolated data sets. In case of the Minimum Curvature method, we could generate the interpolated data sets only for anisotropic factor of 1,2,4,6 and 8, because the system was taking lot of computation time for higher orders of anisotropic factor.

While interpolating data with Radial basis even for default anisotropic value i.e. 1, was proved to be very time consuming. For single interpolation it took around 25 minutes for default setting of the anisotropic factor. And the resultant values for radial basis was very much different than to the actual data sets.

In order to study the difference of the actual data sets and the interpolated data sets, the root mean square error or RMS error (Chang, Kang-Tsung, 2006) values have been estimated as shown in equation below:

$$RMS\ error = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(data_{actual} - data_{estimated})^2}$$

Where n is the number of data points and data is the sample value.

Since interpolated data are the velocity data, so value of the RMS error have been computed for the difference in the actual velocity and interpolated velocity and shown in figure 3, 4 & 5 respectively for Kriging, Inverse and Minimum Curvature methods. Each method shows their dependence of RMS error with varying anisotropic factor.

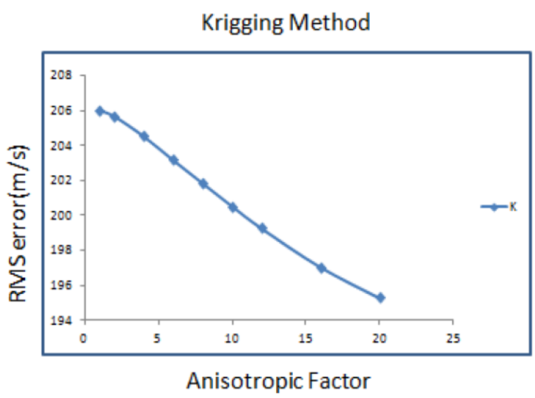

Figure 3. RMS error (Velocity) variations with anisotropic factor for kriging method.

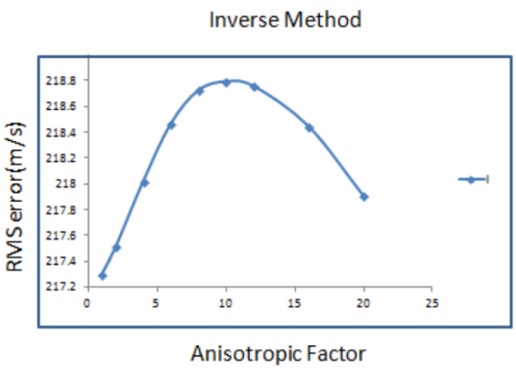

Figure 4. RMS error (Velocity) variations with anisotropic factor for Inverse Method.

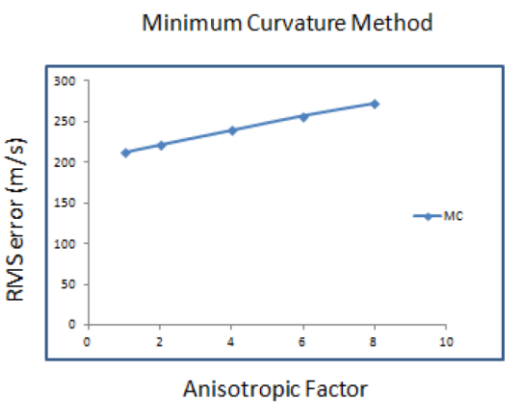

Figure 5. RMS error (Velocity) variations with anisotropic factor for Minimum Curvature method.

It is very significant from figure 3 that the RMS error decreases with increasing anisotropic factor for Kriging method.

In figure 4 unlike Kriging, Inverse Method is showing different scenario. The RMS error initially increases with increasing anisotropic factor till it reaches an isotropic factor 10, and then decreases thereafter.

The Minimum Curvature method is having gently increasing RMS error with increasing anisotropic factor. This is shown in figure 5. If we compare the average values of RMS error for these three methods, Kriging is having 201, Inverse is having 218 and Minimum Curvature is having 241. It is quite evident here that interpolated value using Kriging is much closer to the actual data values.

Eldrandaly K. A. etal in 2011 also demonstrated the comparison of six interpolation methods for the air temperature and found that the Kriging were superior to other tested methods.

We have also tried to see these RMS errors in terms of percentage variation from the average value of the actual velocity data. The RMS error in percentage versus anisotropic factor for all the method is shown in figure 6.

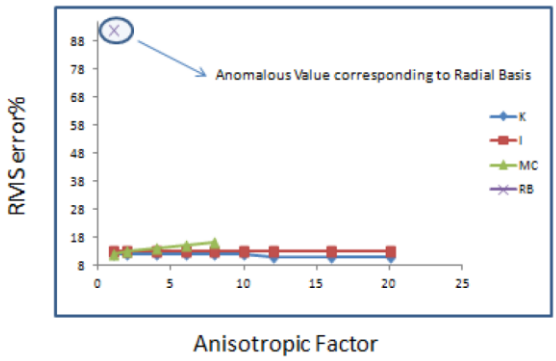

Figure 6. RMS error % with anisotropic factor

It is important to mention that Radial Basis Function is having anomalous value of RMS error % corresponding to anisotropic factor 1. Computing with radial basis was very time consuming and giving values very far from the true data values. It is important to mention that the Radial Basis Function produces good results for gently varying data values. However, this technique is inappropriate when large changes in the data values occur within short distances. This is worth to mention here that velocity field in our data varies abruptly at each interface. This might be the possible reason that anomalous value of difference between the actual data and the interpolated data set using Radial Basis Function.

The anomalous value of Radial method has been removed to see the effect of the remaining interpolation techniques. This is being done to improve upon the scale factor in figure 6.

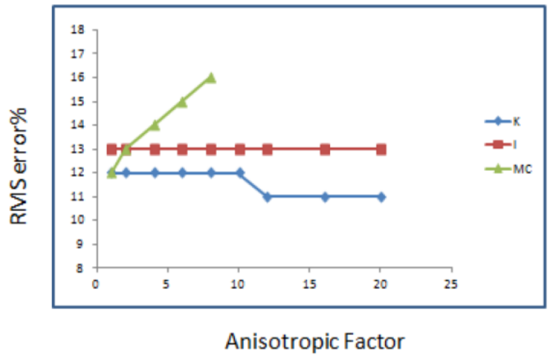

Figure 7. RMS error % with anisotropic factor.

From figure 7, it is evident that Minimum curvature and Kriging is having the same RMS at default anisotropic factor i.e. 1. However Inverse method is not much affected by changing the anisotropy factor. It is also very important to mention that appreciable drop in RMS % comes at anisotropic factor 12 for Kriging.

The velocity models (Fig. 8a & 8b) have been prepared by interpolating with kriging method using anisotropic factor 6, depth is at y-axis and cross line distance at x-axis. The colored contours shows the velocity in meter/sec of the near surface layers and the vertical black bars within the model shows uphole locations with controlled values. Figure 8 a shows the velocity model along line AA' with all datasets i.e. without removing datasets and velocity model with removed data sets is shown in figure 8b.

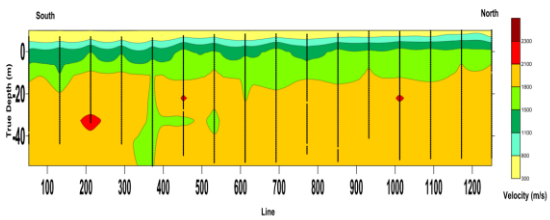

Figure 8a. Velocity model without removing the data

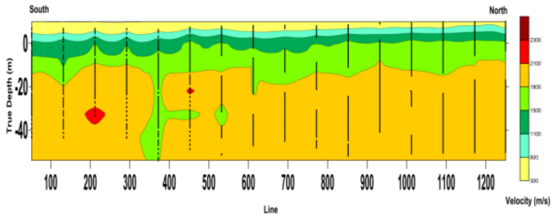

Figure 8b. Velocity model with removed data

Conclusion

The convergence of available results shows that the difference between the interpolated data sets and actual data sets are minimum for the case of kriging method. The interpolated data sets are having less RMS error for increasing anisotropic factor. In case of Inverse Method the RMS error increases till the anisotropic factor increases to value 10, later on RMS error decreases (figure 4), but the change is not so significant to see the appreciable effect as evident from figure7. For minimum Curvature method the scenario is totally different, the RMS error increases with increasing anisotropic factor. Radial Basis could not be analyzed due to two reasons, firstly it involves too much computation time, and secondly the RMS error is very high.

Figure 8 a shows the velocity model along line AA' with all datasets i.e. without removing datasets and velocity model with removed data sets is shown in figure 8b.

By visual inspection of these models it is very difficult to find out any apparent difference since the contouring interval varies from 500 m/sec to 300m/sec. But insight into the RMS error % , we could able to make out some differences in the results of interpolated data.

The minimum RMS % error is 11.2 for kriging and maximum RMS % error is 15.7 for Minimum Curvature method .Even if we compare the average RMS % error of all the methods, the average values of RMS error % for Kriging Method is 11.7, for Inverse Method is 13.0 and for Minimum Curvature Method is 14.0. This shows that the kriging seems to be more reliable as far as our present data set is concerned. Hence Kriging Method is much closer to the true data sets and more reliable to use for our data sets of uphole for deciding the critical information like velocity and depth.

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Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

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Online surfer manual