Anisotropic Reservoir Characterization Based on Support Vector Machine Technique

Yexin Liu*
Calgary, AB
yexinliu@gmail.com

Summary

Because the well data is a sparse and the seismic is low vertical, to combine both dataset is important for reservoir characterization. The interpolation technique is one way to integrate both dataset to build a reservoir model. Usually there are two groups for interpolation. One is deterministic methods, such as Inverse Distance Weight, another group is geo-statistic. The kriging is one of common geo-statistical methods and also popular at petroleum industries. However, deterministic methods can not handle multivariable, such as seismic attributes, and Kriging method is more complex to generate the variogram and also is not easy to handle the anisotropy of the reservoir property. Here we present a method, Support Vector Machine (SVM), which can handle both multi-variable and anisotropy of the property.

Support vector machine has been gaining popularity in regression due to its excellent performance at the time of dealing with sparse inputs. The well logging is a space sparse, but seismic has high resolution in the space direction compared with well logging. The SVM technique can combine the sparse well dataset and seismic attributes to construct a reservoir characterization model and also can consider the anisotropy of the reservoir property.

The SVM will perform at the flow-oriented (s, n) coordinate system to handle the anisotropy of reservoir property. The Cartesian (*x*, *y*) coordinate system of both seismic and well will be converted into the flow-oriented system.

The method has demonstrated a reasonable result.

Introduction

Reservoir characterization is a conceptual model of a reservoir or oil and gas field, which can be constructed from sparse data, such as well data or from low vertical resolution data, such as seismic data, or a combination of both dataset. The construction of reservoir characterization model can be performing by deterministic methods (Inverse Distance Weighted), or geo-statistical methods (Kriging).

The deterministic methods make predictions from mathematical formulas that form weighted averages of nearby known values. For example, to predict a reservoir property for any non-well location, Inverse Distance Weighted uses the known well values surrounding the prediction location. The known values closest to the prediction location have more influence on the predicted value than those that are farther away.

Kriging, one of geo-statistic methods, uses variogram to express the spatial variation, and minimizes the error of predicted values which are estimated by spatial distribution of the predicted values. Krigging also works with more than one variable, considering a different trend for each variable.

However, there are some challenges for the current interpolation techniques. Usually there are more seismic attributes, seismic impedance and well information available to construct the reservoir characterization model. The deterministic method can only use the distance variable, and multiple variables Kriging (cokriging) has to generate more semivariograms and more complex cross-variogram models to build a cokriged map. Also if there is only little well information available, a reasonable variogram is difficult to generate. Here we present a new method, Support Vector Machine (SVM), to predict a value for any unmeasured location.

SVM has been gaining popularity in regression and classification due to its excellent performance at the time of dealing with sparse inputs. The idea behind SVM is quite simple. During the training phase, the SVM will develop a functional mapping between an input vector (seismic attributes) and a target output (well properties, such as porosity). The functional is later on used to predict the properties at any non-well locations where only seismic attributes are known.

Because of the anisotropy of reservoir property, the SVM will perform at the flow-oriented (s,n) coordinate system. The Cartesian (*x*, *y*) coordinate system of both seismic and well will be converted into the flow-oriented system. In the flow-oriented coordinate system, the performance of the SVM method will be improved.

Method

Support Vector Machine

Given a set of seismic attributes and/or seismic inversion impedance $\{\mathbf{x}_n, n = 1,...,N\}$ along with the corresponding well property targets $\{t_n, n = 1,...,N\}$ from several boreholes. The SVM makes predictions based on a function of the form:

$$t(\mathbf{x}) = \sum_{n=1}^{N} \omega_n K(\mathbf{x}, \mathbf{x}_n) + \omega_0$$

where $\{\omega_n\}$ are the model weights, and $K(\mathbf{x}, \mathbf{x}_n)$ denotes the kernel function, such as Gaussian function. During the learning stage, a set of input-target pairs is used to find the model of dependency of the targets on the inputs and estimate the weighting parameters $\{\omega_n\}$. After training, the SVM can make predictions using the seismic attributes and/or seismic inversion impedance.

Anisotropy

Often the reservoir properties have preferred orientations. To study the anisotropic effects, the SVM method is performed in the flow-oriented (s,n) coordinate systems although both our seismic and well dataset are a Cartesian (*x*, *y*) coordinate system. Usually the anisotropy settings include a ratio and angle setting. The ratio is the maximum range divided by the minimum range; the angle (α) is the orientation of the major axis (s direction) (Figure 1). It is common practice to specify a search neighborhood to limit the number of known values that are used to predict an unknown value if there are more samples available. The search boundaries will coincide with anisotropy shape.

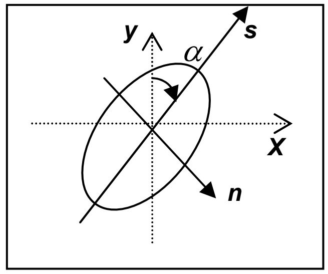

Figure1: The anisotropy settings and search ellipse

Examples

Figure 2 shows an example of the sand-body distribution of fluvial deposition with the anisotropic SVM interpolation. The SVM input variables include seismic Cartesian (*x*, *y*) coordinate, seismic inversion property and seismic attributes extracted from seismic dataset. The azimuth angle is 25 degree and ratio is 1. The angle and ratio can be adjusted according to the river channel direction and deposition facies. During the anisotropic SVM training, both seismic and well coordinate system will be converted to a flow-oriented coordinate system, and the search boundaries will coincide with the anisotropic shape. Figure 3 is another example of the volume of shale distribution. The azimuth angle is 60 degree and ratio is 0.8. The red color is sand and the blue is shale. There are two sand channels and the directions are about North-East 60 degree.

Conclusions

We present Support Vector Machine solution for anisotropic reservoir characterization interpolation. There are a lot of methods which can be used to interpolate the reservoir property. However, the determinstic methods cannot handle the multile variables, and the Kriging method is not easy to generate the variograms and also the results heavily depeneds the variogram trends. The Support Vector Machine method only depends on the input samples and will build a functional mapping using the input samples through a training phase. Not only can the method handle the multile variables, but also can consider the anisotropy of the reservoir property. The search boundaries can share the same shape as anisotropy's. The interpolation results show the method can construct a resonable reseroivr characterization distribution. If combined with the field experience, the anisotropic SVM can easliy help us trace sand body and even give us the well location suggestions using the best reservoir characterization.

References

Yexin Liu and Sacchi M.D., 2003, Propagation of borehole derived properties via a Support. Vector Machine (SVM), CSEG Recorder, December 2003, 54-58

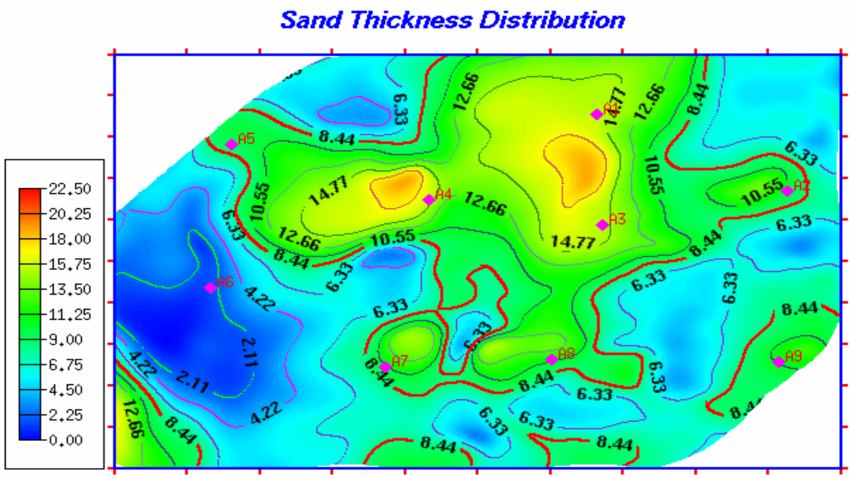

Figure 2: sand thickness distribution with SVM

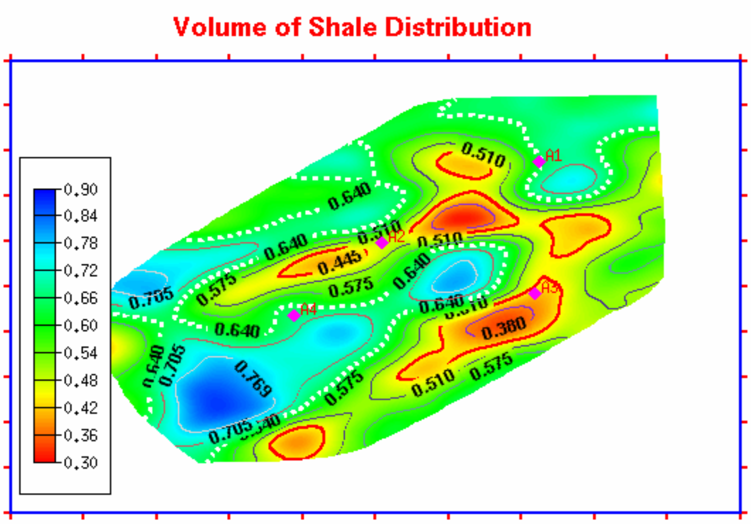

Figure 3: volume of shale distribution with SVM