Application of Hadamard Transform for reservoir lithofacies discrimination

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Summary

This study applies the translation invariant attribute (TIA) using the Hadamard transform of the seismic data to discriminate lithofacies. The Hadamard transform (also known as the Walsh–Hadamard transform, Hadamard–Rademacher–Walsh transform, Walsh transform, or Walsh–Fourier transform) is an example of a generalized class of Fourier transforms. It performs an orthogonal, symmetric operation on $2^n$ real numbers (or complex numbers, although the Hadamard matrices themselves are purely real). The Hadamard transform can be regarded as being built out of size-2 Discrete Fourier Transforms (DFTs), and is in fact equivalent to a multidimensional DFT of a $2^*2^*...*2^*$ size. It decomposes an arbitrary input vector into a superposition of Walsh functions.

In mathematical analysis, the set of Walsh functions form an orthogonal basis of the square functions on the unit interval. The functions take the values -1 and +1 only, on sub-intervals defined by dyadic fractions. The orthogonal Walsh functions are used to perform the Hadamard transform, which is very similar to the way the orthogonal sinusoids are used to perform the Fourier transform. The Walsh functions are related to the Rademacher functions; They both form a complete orthogonal system.

The Hadamard transform is particularly good at finding repeating, stacked vertical sequences. The dyadic shifts represent the invariant properties of the Hadamard transforms. The output of a translation invariant transform is insensitive to the dyadic shifts so that in geologic applications, the objective of using these transforms is to find a geologic pattern which have been analyzed anywhere in the time series, irrespective of their vertical position.

If $z$ is the output of a dyadic shift invariant transform, such as the Hadamard transform, of a sequence $x$, then the dyadic shift invariant power spectrum ($\sum z^2$), is termed as the translation invariant attribute. The translation invariant attribute computation requires $2^n$ input samples. If an input sequence does not have $2^n$ samples, then either zero padding or quite a large time window can be used to make $2^n$ samples.

This attribute is applied in 3D seismic data of Sarvak Formation of one of the oil fields in the south-west of Iran. The Sarvak Formation for this oilfield is a carbonate unit gradually overlying the Kazhdumi Formation. The thickness of Sarvak Formation increases towards the west and varies between 582 m and about 700 m. The reservoir facies for this field are classified based on their porosities. Four porosity facies were selected by using porosity logs of four vertical wells drilled in this oil field. All the seismic data are converted to those categories by Artificial Neural Network (ANN). The
neural network used here was a Two-layer Feed-forward network with Error Back Propagation (EBP) for learning algorithms. The transfer function of the hidden neurons was hyperbolic tangent and the transfer function of the output neurons was linear. Three different time slices of Hadamard transform, translation invariant attribute were presented. The correlation between the real porosity and the predicted porosity using ANN was estimated to be about 81%. Finally, all the seismic data were converted to porosity facies by using ANN and three time slices of the porosity facies were calculated and shown.

**Key words:** Hadamard transform, Walsh function, reservoir facies, porosity, Sarvak Formation, neural network