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Approximation of the reservoir permeability model using ILS-DLA learning algorithm and LARS sparse coding method

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Summary

In this paper, the task is to return from a set of multiplicities from a model to obtain an approximation of that model using sparse approximation. The term 'approximation' indicate the sufficiency of an interpretation that is close enough to the true mode, i.e. reality. In geosciences, the multiplicities are provided by multiple-point statistical (MPS) methods. Realistic modeling of the earth interior demands for more sophisticated geostatistical methods based on true available images, i.e. the training images. Among the available MPS methods, the DisPat algorithm is a distance-based MPS method, which generates appealing realizations for stationary and non-stationary training images by classifying the patterns based on distance functions using kernel methods. Advances in non-stationary image modeling is an advantage of the DisPat method. Realizations generated by the MPS methods form the training set for the sparse approximation. The sparse approximation is comprising of two steps, sparse coding and dictionary update, which are alternately used to optimize the trained dictionary. Model selection algorithms like LARS are used for sparse coding. LARS optimizes the regression model sequentially by choosing a proper number of variables and adding the best variable to the active set in each iteration. The ILS-DLA dictionary learning algorithm addresses the internal structure of the dictionary by considering the overlapping or non-overlapping blocks and the inversion task according to the internal structure of the trained dictionary. The ILS-DLA is fast in the sense that it inverts smaller blocks constructing the trained dictionary rather than inverting the entire dictionary. The trained dictionary is sequentially updated by alternating between sparse coding and dictionary training steps. According to the experiments, the compressed sparsity-based image model is superior to 90% of the generated realizations by 90% probability.

Introduction

In reservoir characterization and modeling, providing a large set of population samples is practically impossible unless introducing stochasticity in the models using the MPS methods. DisPat algorithm is one the MPS methods that is robust for integrating data based on visual system of the human being and representing new algorithms for modeling images with non-stationary properties. The task is to achieve a single model image as the representation of the true model from a large set of MPS realizations, which are considered as the manipulations of the true model. The mathematical tools to perform such a task is known as the sparse approximation.

Methodology and Approaches

DisPat is a distance-based pattern-based multiple-point geostatistical method. In DisPat, the training image is scanned by the designed template and the patterns are extracted from the training image. The patterns are then classified based on distance functions using kernel methods. A distance function measures the distance between each pair of patterns in the metric space. Any two close points in the metric space refer to two similar patterns from the pattern database. The kernel k-means clustering algorithm is used to classify the patterns in the pattern database.

The sparse approximation is a sequential alternation between two steps: sparse coding and dictionary update. The LARS algorithm is used for the sparse coding that is a model selection algorithm used to select a parsimonious set of covariates among a larger set of them. The ILS-DLA algorithm is used for dictionary updating that solves the sparse approximation problem according to the internal structure of the dictionary. The dictionary matrix is blocked into a definite number of sub-matrices, which are either blocky or overlapping. The inversion is performed for each block rather than the whole dictionary, and therefore, it is a fast algorithm.

Results and Conclusions

The three-dimensional (3D) cube seismic data were deterministically inverted and acoustic impedance (AI), porosity, and saturation cubes were obtained. The spectral decomposition cube was generated and studied. Two reality-based permeability models were selected from the spectral decomposition cube based on which, many MPS realizations were generated using DisPat-MPS methodologies. The ILS-DLA learning algorithm was applied on the set of realizations along with the LARS algorithm for sparse coding. The resultant picture model was a compressed model that is superior to 90% of the model images in the training sample by 89.58% probability.