Automated Data Driven 3D Facies Modelling for Reservoir Simulation using Machine Learning Algorithms

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Abstract

We present an integrated data-driven workflow to create realistic 3D models that approximate the complexity of the subsurface and quantitatively classify the facies in the discretized 3D model in the latent space. These 3D reservoir models are produced using a combination of unsupervised machine learning algorithms for data reduction, pattern and anomaly detection. This work presents an inverse method of approaching facies classification to map different geophysical measurements to the underlying physical model in the latent space. To address the non-uniqueness of the inverse solution, the results are quantitatively verified by a rock physics model. As a result, these classes can be interpreted based on their elastic response at well locations and the discretized reservoir model can be used for reservoir simulation. In the area of study, it is challenging to use standard quantitative seismic interpretation methods to define facies and fluids due to the non-uniqueness of the seismic response. The seismic signature can be affected by multiple factors such as frequency, reservoir properties; thickness, porosity, fluids, and the properties of both overburden and substrata layers and their relationship with regard to the reservoir; all of which could interchange simultaneously and contribute to the non-uniqueness of the facies discrimination challenge. To address this, the seismic angle stacks and inverted parameters were combined into a large standardized matrix then reduced using Principal Component Analysis into their main uncorrelated components that explain the variance in the data. Then, the rotated matrix is used as input into a choice of unsupervised classifier (K-means) and the quality of the clustering is validated by its stability through K-fold validation. The number of classes are defined by a combination of class simulation and expected scenarios that are related to resolution and rock properties. Finally, we use rock physics to understand the results of the classification. As a result, the classes can be discriminated using Acoustic Impedance, Vp/Vs and Amplitude information and the facies are interpreted based on a combination of different log responses at well locations such as gamma ray, mineralogy , porosity and predefined lithofacies from sedimentology. The resultant 3D facies model provides details to the reservoir model and showcases the interplay between the porous and tight classes within the channels. However, the model requires further information in distinguishing between the soft signature due to the underlying shale and porous zones. Additional conditions, such as depth can help better discriminate between these two classes. Using these rock physics models, the 3D model can be populated with petrophysical properties to estimate gas in place in preparation for simulation runs for history matching and future forecasting.