Weakly Supervised Structural Interpretation Using Projection Matrices for Latent Space Factorization

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Abstract

Recent advances in deep learning have shown great potential in the field of seismic interpretation. Virtually all facets of deep learning have been combed to advance facies classification, delineation of faults and discontinuities, attribute analysis, reservoir characterization and others. Popular unsupervised learning techniques in seismic research are based on applying Self-Organized Maps (SOMs) to a set of seismic attributes or applying Principal Component Analysis (PCA) for dimensionality reduction with K-Means to cluster a set of reduced attributes into distinct clusters. These unsupervised techniques are based on attributes or feature engineering techniques. Moreover, seismic interpretation is expensive, laborious and subjective among interpreters. Moreso, manually annotated volumes are limited in number which in turn makes it difficult to train deep learning frameworks in a supervised fashion. In this work, we propose a novel unsupervised deep learning framework to weakly annotate seismic images. Our dataset comprises 99x99 patches extracted from the Netherlands offshore F3 block. Each patch contains one dominant geologic structure. We employ an adversarial encoder-decoder architecture to reconstruct each image. Furthermore, two adversarial games are setup in our architecture. First, an adversarial game to generate a latent space that attempts to match the constrained Gaussian latent variable model space (the bottle-neck of the encoder-decoder) into a uniform latent space. Using the principles of information theory, we can show that maximum information in the seismic images datasets are represented in the latent space of the encoder-decoder when the distribution of the latent space is uniform. The second game is

the traditional reconstruction technique that sets up an adversarial game between the encoder-decoder to minimize their KL-divergence. The weak annotation on the seismic image is achieved by further constraining the latent space of the model into two orthogonal subspaces using projection matrices. The projection matrices are constrained to be orthogonal and additive. We demonstrate that with further constraints in the pixel space, the resultant images are weakly annotated and helps in seismic interpretation.

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