Deep Learning: A Step toward Automatic Prestack Interpretation

Deep learning will play a strategic role in the industry's digital transformation.

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Machine learning methods have been applied to geoscience data for more than 25 years, with commercial applications emerging in the early 1990s. These applications were largely focused on the automation of tedious tasks and the classification of digital data. Once considered as nice-to-have technologies, machine learning solutions are rapidly gaining acceptance through a surge in R&D, application experience and the availability of technology as open source offerings. Sizes and diversities of subsurface and surface data are motivating the industry to find alternative methods to analyze data in time frames that are not possible with current methods. Deep learning, a specific type of machine learning, is one such alternative that holds strong promise for solving several challenges with the seismic method.

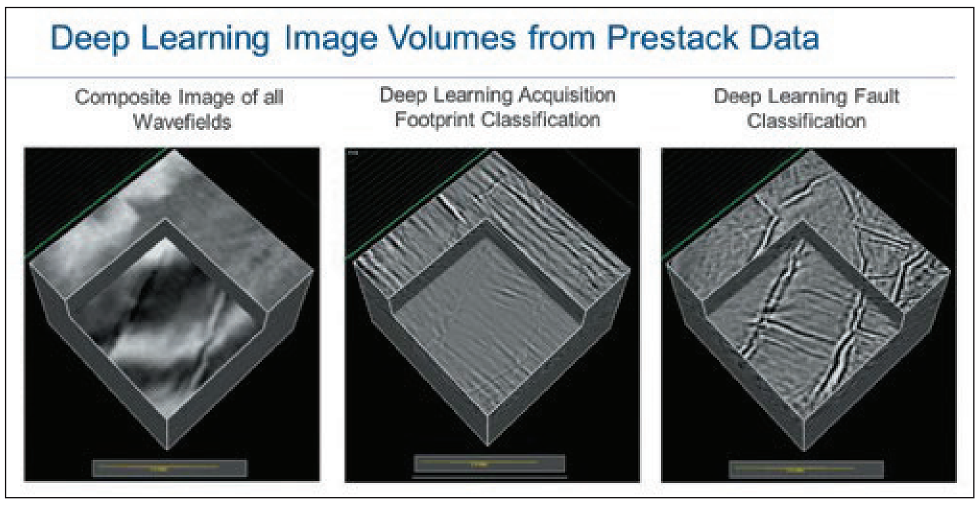
The industry has been advantaged by a wealth of high-density and rich azimuth seismic data, acquired over the past 10 years. These data-rich surface acquisitions sample an equally rich set of subsurface information resulting in different wavefields associated with different subsurface features and conditions. These wavefields carry signatures related to fractures, faults, edges, points and other structural discontinuities, features not always easy to resolve because of size and low illumination energies. When isolated, these wavefields can be used to produce feature-targeted images of unprecedented resolution and clarity. Unfortunately, traditional seismic and imaging procedures routinely impose many averaging (integration) operations on these wavefields preventing their isolation and recovery. Consequently, interpreters must work with composite wavefield images of high signal to noise but low image resolution.

The separation of wavefields cannot be solved with deep learning methods alone. A sophisticated data preparation must be run to allow the image capture of wavefields prior to the generation and application of deep learning filters. This problem is solved by using a full-azimuth (FAZ) prestack depth imaging procedure carried out in the local angle domain (Emerson's EarthStudy 360) to generate FAZ reflection angle gathers and FAZ direction angle gathers. Each directional angle gather consists of thousands of traces (directions) illuminating each subsurface point from a rich spectrum of angles. More importantly, these gathers contain all the wavefields in a recoverable format.

Since the directional angle gathers include thousands of illumination directions, and subsurface features respond to specific ones, principal component analysis (PCA) is run to isolate the principal directivities and reduce the dimensionality of the data. Each principal component (PC) is related to a different image pattern, associated with a certain subsurface geometrical object, such as continuous structural surfaces (reflectors), faults and fracture systems, point diffractors and coherent and ambient noise. The process compresses the image data into a small set of informative data components, which can be efficiently classified.

Deep learning differentiates and classifies features or objects. It is carried out with a convolutional neural network, a network of many layers, neurons and connectors to support many inputs. Each layer of the neural network detects a certain characteristic of the wavefield that allows the network to classify subsurface features of different scales and energies. To become efficient at seismic feature classification, thousands of data records (or models) are required to train the network. This rich training set can be generated with methods that use different apertures or different seismic surveys. Once training is complete, the results of the training are used to predict the classes in the rest of the (unlabeled) data.

The process is both automatic and powerful. Interpreters no longer have to work with a composite (average) image of many wavefields. Instead, they can work with image volumes constructed from FAZ prestack data that emphasize targeted subsurface features. Preliminary results show remarkable image clarity for features that may not even be recoverable with standard imaging methods. Deep learning has other applications for seismic data and will play a strategic role in this digital transformation. ■



This comparison shows image volume (all wavefields) versus deep learning classification of acquisition footprint energy and fault energy. The separation of wavefields is enabled by the creation of FAZ direction angle gathers, principal component analysis and deep learning. (Image courtesy of Emerson Automation Solutions)