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E-x method for seismic trace interpolation

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Seismic trace interpolation is often necessary to generate better images during the stacking, migration, or other phases of seismic data processing to address problems such as irregularly distributed or noisy traces. Commonly used point-wise interpolation methods, such as the geostatistical or Krige and MINimum Curvature (MINC) methods, do not work well for trace interpolation because they are not suitable for the high spatial and temporal heterogeneity of seismic recording. Noise and the limited bandwidth in seismic data impede the identification and tracing of reflectance events across traces, which greatly limits the performance of those methods that rely on this as the first step. A key improvement in seismic trace interpolation appeared with the development of the F-x, F-K, and a series of other related methods. The F-x method is based on a self-regression model in the frequency domain that predicts higher frequency components using low frequency information and can give the optimized results for linear reflectance events. Further more, the F-x and related methods require regularly sampled traces and linear reflectance events. Simultaneously, the F-K method estimates the non-existent high frequency components of the interpolated traces by iteration, using the known traces as constraints. The F-K method also requires that recorded seismic traces have the same equal interval and it is not able to assure convergence of the high frequency component estimation during the iteration procedure.

In this approach, a new seismic trace interpolation method, E-x, is introduced which interpolates seismic traces in the Eigen and spatial (x) domains. It is based on the fact that the acquired seismic traces span an eigen-space. It can also be understood as the inversion problem of spatial principal component analysis using the covariance, not correlation, matrix of observed seismic traces. If the eigen-traces concept is defined as the eigen-vectors of the recorded seismic traces, then all eigen-traces can compose an orthogonal base for the spanned eigen-space. Thus one known trace will correlate to one point in the eigen-space and a series of recorded traces sorted spatially (such as along a profile) will correlate with a trajectory of points in the eigen-space. Then, a trace interpolation becomes as easy as searching for a certain point along that trajectory and inversely transforming that point to get an estimated seismic trace. The singular spectrum analysis (SSA) technique can describe the energy distribution of these eigen-traces. The E-x method can also be used for noise reduction by selecting a subspace of the eigen-spaces in the inverse transformation. The E-x method is specifically designed for seismic trace interpolation and does not assume linear seismic reflectance events, knowledge of their true dips, or equally sampled traces.

Synthetic and observed marine seismic profile data from the east coast of Canada are processed using the developed E-x method to demonstrate and verify the accuracy and performance of this method for trace interpolation and noise reduction. Future developments allow for the possibility of extending and integrating the E-x method with other methods.

Key words: Seismic trace interpolation; Noise reduction; Eigen-trace; Inverse spatial principal component analysis; Singular spectrum analysis (SSA)