Tau-P seismic data processing: fast slant stack using the Hartley Transform

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A primary objective of seismic data processing is to recover the reflection series from a recorded trace. In this aspect slant stacking provides a computational procedure to compose and decompose wave expansions of the data. For example, a VSP section transformed to the T-P plane assigns the upgoing and downgoing wave fields to different T-P quadrants according to their dips. Either wave field can be reconstructed by an inverse transform after windowing in the T-P plane. Cylindrical slant stack procedures permit a plane-wave decomposition with amplitude preservation thus eliminating the need for spherical divergence corrections. This property is useful for amplitude based analysis.

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Unlike the Fourier analysis of 2-dimensional seismic data which examines the transformed waveform in the f-k domain, slant stack analysis looks at the intercept time (T) versus horizontal phase velocity or the ray parameter (P) instead. Here, linear refraction arrivals and simple hyperbolic reflection curves are transformed into spatially assigned points and ellipses respectively. In the T-P domain a variety of seismic processing methods can be applied to filter and interpret the original input data (e.g. selective muting, velocity analysis, NMO, migration, inversion). The Radon transform (RT) or slant stack gather (T-P) as commonly used in exploration geophysics is related to the Fourier transform (FT) by the projection slice theorem. This states that the 1-D FT of the RT yields the 2-D FT along a line (slice) in the 2-D frequency plane. The RT can be calculated using three 1-D FT applications (row-column decomposition and then along a line $k_x = pw$). In the process storage space must be created for double the input array. The Hartley Transform (HT), described by Bracewell (1984, 1986), was developed as a FT substitute in cases where the input data are in the real domain. This condition is compatible with acquired seismic field data.

Applying the above properties, an alternative method for computing the slant stack using the Hartley Transform instead is introduced here. The projection slice property connecting the 2-D Fourier transform with the Radon transform is extended here to connect the 2-D Hartley transform with the Radon transform. Slant stack of seismic data can be computed by a triple application of the 1-D Hartley transform. The useful formulation of the Hartley transform without the need for complex arithmetic reduces memory space and decreases program execution time when compared with the Fourier transform applied three times during calculation of a slant stack gather.

The fast slant stack using the Hartley Transform could be the answer in lowering processing costs. Hence, it can encourage hydrocarbon exploration companies to utilise the many benefits of fast slant stack in routine processing.