Improving GPR Trace Regularity: Application of RNA and PWC Methods for Accurate Geological Interpretation

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Abstract

Geophysical surveys using Ground Penetrating Radar (GPR) in time mode offer high temporal resolution and quick data acquisition. However, these data are susceptible to variations in the movement speed of the equipment. Operator step variations or the vehicle's velocity carrying the GPR can cause discrepancies in trace spacing along the section. This phenomenon, known as the "accordion effect," can result in positioning errors, continuity issues, or suppression of features of interest, such as reflectors and diffractions. Moreover, it adversely affects subsequent processing stages, such as migration, which require equally spaced traces. Given the high precision of GPR data, the accordion effect can significantly compromise data interpretation and the accurate positioning of targets of interest.

Georeferencing the session with Global Positioning System (GPS) data and subsequent interpolation with GPR data is essential to mitigate this effect. GPR and GPS data have different sampling rates. While GPR can emit hundreds of pulses in fractions of a second, GPS data with positioning and time information are obtained approximately every second. Consequently, each trace is assigned position and time information but remains unevenly distributed along the section, necessitating interpolation.

For GPS data adjustment to GPR, a Cubic Spline interpolator is employed on GPS data to match the number of positioning points to the number of GPR traces. This process results in a GPR header with interpolated GPS data (x, z). Incorporating this header results in irregularly spaced GPR traces, requiring a second interpolation on the GPR data to regularize trace spacing.

This study applied two interpolation methods: Regularized Nonstationary Autoregression (RNA) and Plane-Wave Construction (PWC). RNA uses adaptive prediction error filters that compensate for missing data and incorporate regularization to stabilize the solution, providing smooth and continuous interpolation that respects the underlying data structure. PWC involves estimating local slopes of GPR events using the PWC operator and then using these slopes to interpolate missing or irregularly sampled data points. This ensures that the interpolated data preserves the continuity and structure of GPR events.

A layered model with randomly distributed diffractor points in X and Z was created to test these interpolation methodologies on GPR data. Sections were decimated in various ways, either randomly or at varying intervals, simulating acquisition with differing speeds. The results indicated that the PWC interpolator recovered diffractor events more effectively than RNA for the model. Consequently, the PWC method was chosen to interpolate Real data acquired in Salinópolis, a coastal region in Pará. The final result presented high-quality interpolated data with enhanced assurance in trace positioning, improving the reliability of the results and, consequently, the interpretation of geological events.