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Reconstruction of GPR data using multiple-point geostatistics

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A common challenge in the processing and analysis of ground-penetrating radar (GPR) reflection data is the reconstruction of missing traces. Gap filling, for example, may be required where data could not be recorded in the field in order to reduce artifacts produced during migration. Similarly, proper visualization and imaging of a GPR profile requires an even trace spacing, meaning that trace regularization is typically needed when the data are acquired in continuous mode using a fixed trace acquisition rate. Lastly, we may wish to increase the spatial resolution of a GPR dataset through trace densification, whereby new traces are reconstructed between existing ones, in order to improve data interpretability.

A number of methods have been proposed for the reconstruction of missing GPR data over the past few decades, which vary in their degree of complexity and underlying assumptions. Simple strategies such as linear, cubic, and sinc interpolation can be highly effective, but only in the absence of spatial aliasing. When aliasing is present, other methods that exploit the predictability and/or sparseness of the GPR data, commonly in a transformed domain, may be utilized. However, such methods often involve overly simplistic assumptions about the data structure (e.g., that windowed portions of data can be described by sum of plane waves), which can lead to unrealistic and linear results as gaps in the data become large. Finally, all current reconstruction approaches lead to a single "best" estimate of the missing traces based on the existing measurements and some explicit or implicit choice of prior information, with no consideration of the corresponding uncertainty.

Here, we attempt to address these shortcomings by considering a GPR data reconstruction strategy based on the QuickSampling (QS) multiple-point geostatistical method. With this approach, GPR traces are simulated via sequential conditional simulation based on patterns that are observed in nearby high-resolution data (training images). To demonstrate the potential of this approach, we show its successful application to a variety of examples involving gap filling, regularization, and trace densification.