Optimal Design of Seismic Sensor Arrays with Applications to Continuous Tomographic Monitoring

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Abstract

Geophysical monitoring techniques offer the only approach capable of assessing both the spatial and temporal dynamics of subsurface fluid processes. Historically, monitoring datasets have consisted of surveys sequentially collected using acquisition geometries and sensor platforms similar to static measurements. Unfortunately, a host of logistical constraints hamper the repeatability of such surveys, particularly difficulties replicating the source/receiver geometry. Increasingly, permanent sensor arrays in boreholes and on the ocean floor are being deployed to improve the repeatability and increase the temporal sampling of monitoring surveys. Because permanent arrays require a large up-front capital investment and are difficult (or impossible) to re-configure once installed, a premium is placed on selecting a geometry capable of imaging the desired target at minimum cost. We will present a simple approach to optimizing downhole sensor arrays for monitoring experiments making use of differential seismic traveltime tomography. In our case, we use a design quality metric based on the accuracy of tomographic reconstructions for a suite of imaging targets.

By not requiring an explicit SVD of the forward operator, evaluation of this objective function scales to problems with a large number

of unknowns. We also restrict the design problem by recasting the array geometry into a low dimensional form more suitable for optimization. A side effect of using these restrictive parameterizations for experiment geometry is a well-behaved objective function more amenable to local search techniques. To demonstrate the efficacy of our algorithm, we will consider a series of possible designs for a next-generation tomographic monitoring experiment still within the conceptual development phase.