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Optimal experimental design for placement of boreholes

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Drilling for deep resources is an expensive endeavor. Among the many problems finding the optimal drilling location for boreholes is one of the challenging questions. We contribute to this discussion by using a simulation based assessment of possible future borehole locations. We study the problem of finding a new borehole location in a given geothermal reservoir in terms of a numerical optimization problem.

In a geothermal reservoir the temporal and spatial distribution of temperature and hydraulic pressure may be simulated using the coupled differential equations for heat transport and mass and momentum conservation for Darcy flow. Within this model the permeability and thermal conductivity are dependent on the geological layers present in the subsurface model of the reservoir. In general, those values involve some uncertainty making it difficult to predict actual heat source in the ground. Within optimal experimental the question is now at which location and to which depth to drill the borehole in order to estimate conductivity and permeability with minimal uncertainty. We introduce a measure for computing the uncertainty based on simulations of the coupled differential equations. The measure is based on the Fisher information matrix of temperature data obtained through the simulations. We assume that the temperature data is available within the full borehole. A minimization of the measure representing the uncertainty in the unknown permeability and conductivity parameters is performed to determine the optimal borehole location.

We present the theoretical framework as well as numerical results for several $2d$ subsurface models including up to six geological layers. Also, the effect of unknown layers on the introduced measure is studied. Finally, to obtain a more realistic estimate of optimal borehole locations, we couple the optimization to a cost model for deep drilling problems.