
Optimization of Mineral Exploration Borehole Planning Using Partially Observable Markov Decision Processes with Belief-based Rewards

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The placement, orientation, depth, and sequence of exploration boreholes controls rate of discovery and orebody delineation. The current state-of-the-art is to determine an optimal pattern of exploration boreholes based on expert judgement. However, using these purely expert-based methods does not incorporate quantitative optimization with stochastic geological models which more accurately reflect uncertainty of the subsurface. Here, we formulate mineral exploration as a partially observable Markov decision process (POMDP), and determine the optimal configuration and sequence of exploration boreholes by solving the POMDP using a reward function based on efficacy of information. Due to the complexity of the subsurface and many possible configurations of boreholes, the solution to optimal borehole placement is difficult to compute. In order to address this, we need to choose and apply approximations in exploration borehole optimization. Three approximations are studied: complexity of geological models, the detail of drilling observations, and the set of candidates of proposed boreholes. In our formulation for exploration drilling, geological features are parameterized as simple geometric objects (rather than wireframe or implicitly modeled objects), which enables quantified uncertainty reduction on economic parameters of an orebody such as size, shape, and depth, or combinations thereof (e.g. volume). We study the impact of using fully detailed versus simplified versions of borehole logs when updating the geological model with new data, and find that using fully detailed observations is not necessary. Finally, we optimize for sets of proposed boreholes, and also show optimal targeting when the locations of proposed boreholes are unknown. We demonstrate our results on a case study in the Midcontinent Rift.