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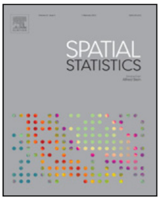

Distance function modeling in optimally locating additional boreholes

Mohammad Safa, Saeed Soltani-Mohammadi *

Department of Mining Engineering, University of Kashan, Ravand Street, P.O. BOX: 87317-51167, Kashan, Iran

HIGHLIGHTS

- Using distance function reduces the calculation time.
- A new algorithm for locating the additional boreholes is presented.
- The algorithm is validated based on the Angouran mineral deposit.

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ABSTRACT

The optimal locating of additional boreholes is complicated and very time consuming. Some methods such as metaheuristic algorithms, calculation parallelism, and reducing the time of objective function calculation could be used to increase the calculation speed; among these methods, the latter is preferred due to its extensive influence on the optimization of time. The main reasons that make the objective function calculation cumbersome are mentioned hereafter, and according to their priority: (1) excessive quantity of blocks in the geological block model, and (2) inverting the matrix of average semivariogram between samples is a time consuming operation. The present study aims to decrease the calculation time by reducing the number of blocks without considering their size increment that affects accuracy. To achieve this purpose, the objective function is calculated according to the block model of uncertainty zone, which is defined by using the recently introduced distance function to investigate uncertainty in mineralized domain boundaries. In order to evaluate the performance of the present approach on reducing the calculation time as well as the precision in locating additional boreholes,

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* Corresponding author.
E-mail address: saeedsoltani@kashanu.ac.ir (S. Soltani-Mohammadi).

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the results from particle swarm optimization as a metaheuristic algorithm are compared by considering two different scenarios of combined variance reduction on the basis of a three-dimensional geological block model and an uncertainty block model. The comparative results show that using the uncertainty block model reduces the calculation time by one-third, and the proposed locations of the boreholes are more consistent to the study's aim, which is to reduce the boundary's uncertainty.

1. Introduction

The 3D geological block model is utilized as a tool to illustrate the information collected from mineral deposits, and it is one of the main input parameters for various operations in mining projects such as feasibility study, planning, scheduling, etc. Mineral deposits are usually relatively heterogeneous mediums, and so their geological block models should be constructed based on the grade spatial continuity and by considering geological features such as their petrology, mineralogy and metamorphism (Duke and Hanna, 2001; Ortiz, 2006). Due to the limited number of samples collected from deposits, the geological model is tainted by uncertainty (Yamamoto et al., 2014). The uncertainty is known as a source of risk in the future phases of mine planning and decision making (Dimitrakopoulos, 1998). The uncertainty of geological modeling could be sorted into three categories: (1) uncertainty in boundary delineation, (2) uncertainty of interpolation inside the data range and extrapolation beyond the data range, and (3) lack of knowledge about underground structures such as the existence of faults (Mann, 1993).

The grade reduction in deposit boundaries follows a gentle trend that makes the exact delineation of boundaries impossible (Tercan, 1998). Defining the boundary's type requires extensive research and collection of data relevant to grade variation, rock type and geological facies (McLennan, 2008). Generally, it can be stated that two kinds of problems arise without the full and extensive sampling from boundary zone: first, the amount of overestimation in deposits geological extension is much more than expected, and second, the estimated values may lie in a range that is not logical from a geological viewpoint (Pawlowsky et al., 1993). The first problem can be usually solved by defining the boundary with a value less or greater than a predetermined value, while the second problem remains, and its impact could be noticed in several maps in which the contours are not closed lines in the marginal areas that then suddenly intersect with the boundary. To overcome these problems, geostatistical methods such as indicator kriging (Larrondo and Deutsch, 2005), probability kriging (Tercan, 1998) and geostatistical simulation (Dohm, 2003) could be utilized to evaluate the uncertainty in geological boundaries and improve the geological boundary delineation techniques.

Uncertainty reduction obligates increment of data quantity, which means additional drilling. Increasing the number of samples does not always lead to reduction in uncertainty, and it depends to a great extent on the locations of new samples (Yamamoto et al., 2014). Therefore, many researches have focused on optimizing the number of additional boreholes (Soltani-Mohammadi and Safa, 2015; Szidarovszky, 1983) and locating additional boreholes (Hossein Morshedy and Memarian, 2015; Scheck and Chou, 1983; Walton and Kauffman, 1982). Preliminary studies on the optimization of exploratory drilling pattern have been carried out manually in a two dimensional space and usually by means of an objective function defined on the basis of the kriging variance (Kim et al., 1977; Walton and Kauffman, 1982). Although the result of this method is preferable to making use of experts' experiences for locating drill holes, the simplification of the procedure by 2D assumption is considered as its drawback because the 3D effects of the grade and thickness variations are not accounted for in this assumption. Soltani and Hezarkhani (2009) solved the optimal locating problem in 3D space, but this improvement caused an increase in the calculation time (Soltani and Hezarkhani, 2009). Recently, researchers have made improvements in reducing the calculation time in 3D cases through the utilization of different metaheuristic optimization algorithms such as simulated annealing, partial swarm optimization and genetic algorithm (Cheng, 2016; Dali and Bouamama, 2015; Lee, 1997; Roeva