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Application of Harris Hawks Optimization Metaheuristic Algorithm and Random Forest Machine Learning Method for Long-Term Production Scheduling Problem under Uncertainty in Open-Pit Mines

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Abstract : In open-pit mines, the long-term production scheduling optimization problem (LTPSOP) is a complicated problem that contains constraints, large datasets, and uncertainties. Uncertainty in the output is caused by several geological, economic, or technical factors. Due to its dimensions and NP-hard nature, it is usually difficult to find an ideal solution to the LTPSOP. The optimal schedule generally restricts the ore, metal, and waste tonnages, average grades, and cash flows of each period. Past decades have witnessed important measurements of long-term production scheduling and optimal algorithms since researchers have become highly cognizant of the issue. In fact, it is not possible to consider LTPSOP as a well-solved problem. Traditional production scheduling methods in open-pit mines apply an estimated orebody model to produce optimal schedules. The smoothing result of some geostatistical estimation procedures causes most of the mine schedules and production predictions to be unrealistic and imperfect. With the expansion of simulation procedures, the risks from grade uncertainty in ore reserves can be evaluated and organized through a set of equally probable orebody realizations. In this paper, to synthesize grade uncertainty into the strategic mine schedule, a stochastic integer programming framework is presented to LTPSOP. The objective function of the model is to maximize the net present value and minimize the risk of deviation from the production targets considering grade uncertainty simultaneously while satisfying all technical constraints and operational requirements. Instead of applying one estimated orebody model as input to optimize the production schedule, a set of equally probable orebody realizations are applied to synthesize grade uncertainty in the strategic mine schedule and to produce a more profitable and risk-based production schedule. A mixture of metaheuristic procedures and mathematical methods paves the way to achieve an appropriate solution. This paper introduced a hybrid model between the augmented Lagrangian relaxation (ALR) method and the metaheuristic algorithm, the Harris Hawks optimization (HHO), to solve the LTPSOP under grade uncertainty conditions. In this study, the HHO is experienced to update Lagrange coefficients. Besides, a machine learning method called Random Forest is applied to estimate gold grade in a mineral deposit. The Monte Carlo method is used as the simulation method with 20 realizations. The results specify that the progressive versions have been considerably developed in comparison with the traditional methods. The outcomes were also compared with the ALR-genetic algorithm and ALR-sub-gradient. To indicate the applicability of the model, a case study on an open-pit gold mining operation is implemented. The framework displays the capability to minimize risk and improvement in the expected net present value and financial profitability for LTPSOP. The framework could control geological risk more effectively than the traditional procedure considering grade uncertainty in the hybrid model framework.

Keywords : grade uncertainty, metaheuristic algorithms, open-pit mine, production scheduling optimization
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