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Prediction of jumbo drill penetration rate in underground mines using various machine learning approaches and traditional models

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Estimating penetration rates of Jumbo drills is crucial for optimizing underground mining drilling processes, aiming to reduce costs and time. This study investigates various regression and machine learning methods, including Multilayer Perceptron (MLP), Support Vector Regression (SVR), and Random Forests (RF), to predict the penetration rates (ROP) using multivariate inputs such as operation parameters and rock mass characteristics. The Rock Mass Drillability Index (RDi), incorporating both intact rock properties and structural parameters, was utilized to characterize the rock mass. The dataset was split into 80% for training and 20% for testing. Performance metrics including correlation coefficient (R^2), variance accounted for (VAF), mean absolute error (MAE), mean absolute percentage error (MAPE), and root mean square error (RMSE) were calculated for each method to evaluate the accuracy of the predictions. SVR exhibited the best prediction performance for ROP, achieving the highest R2, lowest RMSE, MAE, and MAPE, as well as the largest VAF values of 0.94, 0.15, 0.11, 4.84, and 94.13 during training, and 0.91, 0.19, 0.13, 6.02, and 91.11 during testing, respectively. With this high accuracy, we conclude that the proposed machine learning algorithms are valuable and efficient predictors for estimating jumbo drill penetration rates in underground mining operations.

Keywords Penetration rate prediction, The Rock Mass Drillability Index (RDi), Traditional models, Multilayer perceptron neural networks (MLP), Support Vector Regression (SVR), Random Forests (RF)

The drill and blast method is the most important method used in underground excavation. In the drill and blast method in tunneling, drilling constitutes the largest cost and time[1]. In drilling operations, many factors such as geological, geotechnical, operational, and machine characteristics, affect drilling performance. These parameters can be generally classified into two major groups controllable and uncontrollable parameters[2,3]. Operational factors and machine characteristics are variables that can be controlled but geological and geotechnical conditions are unique to each site and cannot be easily altered[4]. The key factors that impact the Rate of Penetration (ROP) are shown in Fig. 1.

Predicting the ROP based on drilling variables is essential aiming to maximize ROP or minimize total time or cost. For that, the accuracy of the ROP model is crucial[4]. Despite the importance of predicting ROP for better drilling efficiency, accurately establishing a prediction model is challenging[5]. The empirical approach, commonly used to study penetration rates, utilizes field data and is developed for varying ground conditions. Various studies conducted by researchers on percussive and rotary drilling have revealed that the rate of penetration is contingent upon the properties of the rock[6]. The relationship between rock properties and ROP is complex and nonlinear. Many researchers developed statistical models to predict ROP based on the experimental data[7–17]. Various statistical models and classification systems have been developed to predict penetration rate, but they often lack generalizability across different drilling conditions[18]. Existing methods may not accurately predict ROP in different geological settings or with different drilling rigs[19–24]. Many of these statistical relations only show the effect of different rock parameters on ROP separately. Few of them can predict ROP based on few

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