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Interpretable real-time monitoring of short-term rockbursts in underground spaces based on microseismic activities

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In this study, two novel hybrid intelligent models were developed to evaluate the short-term rockburst using the random forest (RF) method and two meta-heuristic algorithms, whale optimization algorithm (WOA) and coati optimization algorithm (COA), for hyperparameter tuning. Real-time predictive models of this phenomenon were created using a database comprising 93 case histories, taking into account various microseismic parameters. The results indicated that the WOA achieved the highest overall performance in hyperparameter tuning for the RF model, outperforming the COA. RF-WOA model accurately predicted the occurrence of this phenomenon with an accuracy of 0.944. Additionally, for this model, precision, recall and F1-score were obtained as 0.950, 0.944 and 0.943, respectively, indicating that the proposed model is robust in predicting damage severity of rockburst in deep underground projects. Subsequently, the Shapley additive explanations (SHAP) method was employed to interpret and explain the prediction process and assess the influence of input features based on RF-WOA model. The results showed that three parameters including cumulative seismic energy, cumulative microseismic events, and cumulative apparent volume have the greatest impact on the occurrence of rockburst events. This study provides an interpretable and transparent resource for accurately predicting rockburst events in real time. It can facilitate estimating project costs, selecting a suitable support system, and identifying essential ways to limit the danger of rockburst.

Keywords Short-term rockburst, Microseismic monitoring, Random forest, Whale optimization algorithm, Coati optimization algorithm

The phenomenon of rockburst (RB) refers to a dynamic failure (seismic event) that occurs due to the violent and sudden release of elastic energy accumulated within coal or rock formations. This phenomenon can result in significant consequences, including the failure of underground working spaces, potential casualties, deformation of supporting systems, damage to machinery, and delays in construction activities[1–4]. Based on these destructive effects, attention needs to be given to predicting of this phenomenon in underground excavation projects. There are two types of RB prediction: long-term and short-term[5–8]. The long-term prediction of RB is typically conducted during the early stages of excavation and project design, and it serves as a guide for the subsequent excavation phases. Such predictions typically rely on intrinsic rock mechanics parameters (including stiffness, strength, energy storage capacity, and brittleness) to assess the occurrence of this phenomenon at a specific site. On the other hand, short-term prediction is primarily used during the life of the project to quickly detect the occurrence of RB events. This enhances the coordination of industrial activities and reduces the risk of severe accidents. Generally, short-term RB prediction involves assessing the risk of RB occurrences in the near future based on in situ techniques. Among these techniques, microseismic (MS) monitoring is one of the most widely used methods for RB event monitoring due to real-time monitoring, wide detection range, big data scale, and no harm to production[8,9]. In this technique, using sensors laid out spatially with different azimuths, MS waves released during rock fracture can be captured. By analyzing the MS waves, some precursory features of RB events are discovered that could be used to predict the risk of this phenomenon[10–12].

The mechanism of RB occurrence is complex and influenced by a combination of factors. Because of this complexity, RB prediction without the aid of computer models is challenging[13]. Recently, machine learning (ML) methods have been employed to predict RB owing to their capacity to tackle complex and nonlinear

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