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Improving predictions of rock tunnel squeezing with ensemble Q-learning and online Markov chain

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Predicting rock tunnel squeezing in underground projects is challenging due to its intricate and unpredictable nature. This study proposes an innovative approach to enhance the accuracy and reliability of tunnel squeezing prediction. The proposed method combines ensemble learning techniques with Q-learning and online Markov chain integration. A deep learning model is trained on a comprehensive database comprising tunnel parameters including diameter (D), burial depth (H), support stiffness (K), and tunneling quality index (Q). Multiple deep learning models are trained concurrently, leveraging ensemble learning to capture diverse patterns and improve prediction performance. Integration of the Q-learning-Online Markov Chain further refines predictions. The online Markov chain analyzes historical sequences of tunnel parameters and squeezing class transitions, establishing transition probabilities between different squeezing classes. The Q-learning algorithm optimizes decision-making by learning the optimal policy for transitioning between tunnel states. The proposed model is evaluated using a dataset from various tunnel construction projects, assessing performance through metrics like accuracy, precision, recall, and F1-score. Results demonstrate the efficiency of the ensemble deep learning model combined with Q-learning-Online Markov Chain in predicting surrounding rock tunnel squeezing. This approach offers insights into parameter interrelationships and dynamic squeezing characteristics, enabling proactive planning and support measures implementation to mitigate tunnel squeezing hazards and ensure underground structure safety. Experimental results show the model achieves a prediction accuracy of 98.11%, surpassing individual CNN and RNN models, with an AUC value of 0.98.

Keywords Geotechnical engineering, Tunnel construction, Rock mechanics, Ensemble deep learning, Q-learning, Markov chain analysis

Rock tunnel squeezing is a prevalent and challenging issue in underground construction projects, where the surrounding rock mass undergoes deformation and pressure increase, posing significant risks to the stability and safety of tunnels[1]. Accurate prediction of tunnel squeezing phenomena is crucial for effective design, construction, and maintenance of underground structures. Traditional prediction methods for tunnel squeezing often rely on empirical models based on limited datasets, which may lead to unreliable and conservative results. In recent years, there has been growing interest in leveraging advanced machine learning techniques to improve the accuracy and reliability of tunnel squeezing prediction[2–5]. In this study, we propose a novel approach that combines ensemble deep-learning models with Q-learning and an online Markov chain for the prediction of the squeezing potential of rocks around tunnels. Ensemble deep learning involves training multiple deep learning models simultaneously and aggregating their predictions to improve the overall performance[6–9]. By utilizing the potential of ensemble learning, the model is able to capture diverse patterns and variations in the dataset, resulting in more precise and reliable predictions. To further refine the predictions, we integrate Q-learning[10–12] and an online Markov chain[13–15] into the framework. The online Markov chain analyzes the historical sequences of tunnel parameters and squeezing class transitions, constructing transition probabilities between different squeezing classes. This enables the model to capture the dynamic nature of tunnel squeezing phenomena and adjust predictions based on the current tunnel state. The Q-learning algorithm is employed to optimize the decision-making process by learning the optimal policy for transitioning between different tunnel states. By iteratively updating the Q-values based on rewards and penalties associated with different actions, the model can learn and adapt to changing conditions. This iterative approach improvesthe accuracy and reliability of

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