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ORIGINAL ARTICLE

Real-time classification of ground conditions ahead of a TBM using supervised machine learning algorithms

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Abstract

Accurately predicting the ground conditions ahead of a tunnel boring machine (TBM) in real-time is crucial for preventing geological hazards as well as for the adaptive adjustment of TBMs. The subjectivity in ground characterization is a major challenge in rock engineering. There is therefore the need for data-driven approaches. In this study, four machine learning classification models, namely support vector machine (SVM), k-nearest neighborhood (KNN), random forest (RF), and extremely randomized trees (ERT) were used to develop real-time rock mass classification models based on TBM operational parameters from Pahang-Selangor Raw Water Tunnel (PSRWT), Malaysia. Nine TBM operational parameters were used as input parameters. These include boring energy, cutterhead torque, cutterhead thrust force, revolution per minute (RPM), rate of penetration, stroke speed, gripper cylinder pressure, pitching, and motor current amps. An aggregated dataset of TBM operation data and rock mass data were created by adjoining the rock mass record for a particular chainage interval to all the TBM records in that interval. A balanced training set was obtained by the synthetic minority oversampling technique (SMOTE) for unbiased learning. The hyper-parameters of each classifier are optimized using the grid search method. The prediction results indicate that the ERT classifier has a better performance than other classifiers, and it shows a more powerful learning and generalization ability. The results suggest that ERT has the potential to correctly predict rock masses conditions ahead of a TBM in real-time by utilizing TBM operation parameters.

Keywords Tunnel boring machine · Rock mass rating system · Random forest · K-nearest neighborhood · Extremely randomized trees · Support vector classifier

Introduction

Tunnel boring machines (TBMs) have been widely used in numerous large-scale tunnel projects due to its outstanding advantages in safety, economy, efficiency, and are usually suitable for different geologic and environmental conditions compared to the conventional drill and blast method. However, TBMs are sensitive to adverse geological conditions, and the uncertainty of rock mass (Mostafa et al. 2024; Yu et al. 2023). These adverse geological conditions can possibly lead to project delays, increased project costs, and fatalities (Zhou et al. 2022). These tunneling associated risks can be effectively managed and mitigated by efficiently characterizing and classifying the initial ground conditions prior to excavation. Therefore, the operational parameters of the TBM must be adjusted in accordance with the geological conditions to ensure tunnel stability, minimize settlement, and increase the performance of machine (Wang et al. 2021; Wu et al. 2024; Xu et al. 2023).

Under the current industrial practice, three possible approaches have been used to obtain ground conditions ahead of the tunnel excavation. The first method involves the use of soil investigation boreholes during the design phase.

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