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Application of Artificial Intelligence Techniques in Slope Stability Analysis:
A Short Review and Future Prospects

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ABSTRACT

Artificial intelligence (AI) techniques have become a trusted methodology among researchers in the recent decades for handling a variety of geotechnical and geological problems. Machine learning (ML) algorithms are distinguished by their superior feature learning and expression capabilities as compared to traditional approaches, attracting researchers from a variety of domains to their growing number of applications. Different ML models are extensively used in the field of geotechnical engineering to accounting for the inherent spatial variability of soils in slope stability assessments. This study presents a brief overview of the application of several AI techniques in the area of slope stability, including adaptive neuro-fuzzy inference system, artificial neural network, extreme learning machine, functional network, genetic programming, Gaussian process regression, least-square support vector machine, multivariate adaptive regression spline, minimax probability machine regression, relevance vector machine, and support vector machine. Additionally, a summary containing published literature, the corresponding reference cases with the type of input soil parameters, and the implemented ML algorithms was compiled. Recent applications of various hybrid ML models in slope stability assessment are also discussed. Furthermore, the challenges and future prospects of AI techniques development in solving slope stability problems are presented and discussed.

KEYWORDS

Artificial Intelligence, Geotechnical Engineering, Machine Learning, Slope Stability

1. INTRODUCTION

In the parlance of geotechnical engineering, the evaluation of slope stability is a fundamental problem in slope design and maintenance. Material qualities, analytical methodologies, and boundary conditions all contribute to the variability in slope stability forecasts (Kang et al., 2017). With regard to determining appropriate soil properties, geotechnical engineers are well versed. Due to the intrinsic complexity of geotechnical materials, researchers seek to use soft computing methods to tackle numerous geotechnical design challenges and assessment issues, rather than lengthy theoretical solutions (Zhang et al., 2021). Because slope stability problems are characterized by high uncertainty

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and involve a variety of parameters that cannot be determined directly by engineers to estimate the factor of safety (FOS) of slopes, artificial intelligence (AI)-based approaches have grown in popularity. Soft computing techniques, which excel at nonlinear modelling, can capture the complex behaviour of input data and give practical tools for simulating a variety of diverse issues (Bui et al., 2018).

Various machine learning (ML) models for forecasting the intended output(s) in several engineering disciplines have been developed over the last two decades, including prediction of slope stability problems in the geotechnical engineering field. Various ML models, namely adaptive neuro-fuzzy inference system (ANFIS), artificial neural network (ANN), extreme learning machine (ELM), functional network (FN), genetic programming (GP), Gaussian process regression (GPR), least-square support vector machine (LSSVM), multivariate adaptive regression spline (MARS), minimax probability machine regression (MPMR), relevance vector machine (RVM), support vector machine/regression (SVM/SVR) and so on, have been successfully employed in solving slope stability problems (Choobbasti et al., 2009; Hoang and Bui, 2017; Kang et al., 2017; Kumar and Samui, 2014; Kumar et al., 2017; Li and Dong, 2012; Lu and Rosenbaum, 2003; Samui et al., 2013, 2011; Samui and Kumar, 2006; Suman et al., 2016; Bui et al., 2019).

Despite the high performance of traditional ML models, recent research has turned to hybrid computational modelling as a possible alternative for forecasting desired outcomes, including the prediction of the stability of soil slopes. Due to their inability to discover the exact global optimum, traditional soft computing models, such as ANNs, give unsatisfactory results in many cases (Bui et al., 2018). Furthermore, ANNs are more likely to become stuck in local minima, resulting in incorrect findings (Alavi and Gandomi, 2011; Mohammadzadeh et al., 2014). Also, overfitting is a major concern to the success rate of such conventional techniques (Koopialipoor et al., 2019). Integration of optimization algorithms (OAs) and traditional machine learning (ML) models, on the other hand, produces high-performance computational models that balance the exploration and exploitation processes during optimization and provide a flexible and effective method for solving high-dimensional and complex problems (Koopialipoor et al., 2019).

Fig. 1 demonstrates a relationship between AI, ML and related branches. AI is a study, similar to biology or mathematics that examines how to create intelligent systems that can solve problems creatively, mimicking human decision-making. On the other hand, ML is a subset of AI that allows systems to learn and develop without being explicitly programmed. Deep learning (DL) is also a type of ML that achieves significant strength and flexibility by learning. With the increase in records, the

Figure 1. Venn diagram representing the relationships between AI, ML and related branch