ABSTRACT

Understanding the stress changes within the vicinity of an excavation is critical in mining environments and should be accounted for by rock engineers. These changes in stresses have a substantial influence on the strength and deformational properties of rocks and can result to instabilities and rock failure. Rock failure is considered as one of the phenomenon having dire consequences to mining operations. Due to the repercussion of rock failure, rocks are subjected to laboratory testing with the aim of determining the stresses that are likely to result to failure as well as measuring the rock strength. Normally, conventional testing is conducted which focuses on the major and minor principal stress. With further studies, the influence of the intermediate stress was appreciated therefore introducing true triaxial testing which is also used today. These tests are the bases of several failure criterions including Hoek-Brown failure criterion, Mogi 1971 etc. The results retrieved from laboratories are analysed with the aim of determining stresses resulting to rock failure, rock strength as well as rock mass parameters which are normally used in numerical modelling. It has been tradition to use least square regression as a modelling technique. This technique is easy to implement and interpret, however it is a non-robust technique and thus causes inaccuracies when predicting rock failure.

The inaccuracies caused by poor modelling have greater harm than what is expected. Poor modelling in rock engineering can result to the application of inappropriate numerical models, poor support design, rock failure, fatalities and many more. Hence this research focuses on evaluating different modelling techniques. It outlines the capabilities and limitations as well as factors affecting the predictive performance of each technique. True triaxial data of 11 rocks retrieved from scientific journals and books was used. The data included all three principal stresses (major, intermediate and minor) as well as the strength of each rock. In rock failure prediction, a failure criterion is normally chosen. For this research, Mogi's 3D failure criterion utilizing all three principal stresses was used. The laboratory data was modelled using each modelling technique.

The four modelling techniques were divided into two groups' i.e. statistical techniques (least square regression and quantile regression) and machine learning based techniques (logistic regression and k-nearest neighbour).

The statistical techniques made use of regression lines as failure envelopes hence they were strongly affected by indecisive points i.e. points plotting directly on the regression line and can neither be classified as stable nor failing. This had an effect on the performance and accuracy of the model. Furthermore, the least square regression was influenced by outliers as expected. On the other hand, the machine learning based techniques showed a very good predictive performance but were also affected by data pre-processing parameters. Logistic regression was influenced by the cutoff value and the pre-processing stages where the author had to decide on the variables to use since some of the variables were statistically non-significant. K-nearest neighbour was limited by the k-value (neighbourhood values) and the split (ratio between trained dataset and tested dataset). These parameters had an influence on the predictive performance of the models.

The performance of the four techniques were evaluated using different measuring techniques including the coefficient of determination (R^2) for statistical techniques, Receiver Operating Characteristic (ROC) curve for logistic regression and the confusion matrix for all four techniques. Research showed that R^2 is influenced by outliers and the x-axis range and does not give a true reflection of the model's performance. Confusion matrix however is not influenced by any factors hence the accuracies of the models were based on this parameter. K-nearest neighbour had the highest rock failure prediction accuracy followed by logistic regression, then least square regression and lastly quantile regression. Furthermore, the machine learning based techniques were good at identifying and classifying points resulting in failure as they had high sensitivity values while statistical techniques had high specificity meaning they were perfect at predicting stable points. In overall, it was a challenge implementing and interpreting machine learning based models however the rock failure prediction accuracy was higher compared to that of statistical techniques.