Scopus

Documents

Ahmad, M.[a b] , Katman, H.Y.[c] , Al-Mansob, R.A.[a] , Ahmad, F.[d] , Safdar, M.[e] , Alguno, A.C.[f]

Prediction of Rockburst Intensity Grade in Deep Underground Excavation Using Adaptive Boosting Classifier
(2022) *Complexity*, 2022, art. no. 6156210, .

DOI: 10.1155/2022/6156210

[a] Department of Civil Engineering, Faculty of Engineering, International Islamic University Malaysia, Jalan Gombak, Selangor, 50728, Malaysia
[b] Department of Civil Engineering, University of Engineering and Technology Peshawar (Bannu Campus), Bannu, 28100, Pakistan
[c] Institue of Energy Infrastructure, Universiti Tenaga Nasional, Putrajaya Campus, Jalan IKRAM-UNITEN, Kajang, 43000, Malaysia
[d] State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology, Dalian, 116024, China
[e] Earthquake Engineering Center, University of Engineering and Technology Peshawar, Peshawar, 25000, Pakistan
[f] Department of Physics, Mindanao State University-Iligan Institute of Technology, Iligan City, 9200, Philippines

Abstract
Rockburst phenomenon is the primary cause of many fatalities and accidents during deep underground projects constructions. As a result, its prediction at the early design stages plays a significant role in improving safety. The article describes a newly developed model to predict rockburst intensity grade using Adaptive Boosting (AdaBoost) classifier. A database including 165 rockburst case histories was collected from across the world to achieve a comprehensive representation, in which four key influencing factors such as maximum tangential stress of the excavation boundary, uniaxial compressive strength of rock, tensile rock strength, and elastic energy index were selected as the input variables, and the rockburst intensity grade was selected as the output. The output of the AdaBoost model is evaluated using statistical parameters including accuracy and Cohen's kappa index. The applications for the aforementioned approach for predicting the rockburst intensity grade are compared and discussed. Finally, two real-world applications are used to verify the proposed AdaBoost model. It is found that the prediction results are consistent with the actual conditions of the subsequent construction. © 2022 Mahmood Ahmad et al.

Index Keywords
Compressive strength, Excavation, Forecasting, Underground structures; Boosting classifiers, Case history, Developed model, Early design stages, Key influencing factors, Maximum tangential stress, Project construction, Rockburst intensity, Underground excavation, Uniaxial compressive strength; Adaptive boosting

References

- Kaiser, P., Tannant, D., McCreath, D.
(1996) *Canadian Rockburst Support Hand-Book, Geomechanics Research Centre*, Sudbury, Ontario Laurentian University

- Ortlepp, W.
RaSiM Comes of Age - A Review of the Contribution to the Understanding and Control of Mine Rockbursts, pp. 9-11.
Proceedings of the Sixth International Symposium on Rockburst and Seismicity in Mines 2005 Perth, Western Australia

- Wu, M., Ye, Y., Wang, Q., Hu, N.
Development of rockburst research: A comprehensive review
(2022) *Applied Sciences*, 12 (3), p. 974.

- Lu, C.-P., Dou, L.-M., Liu, B., Xie, Y.-S., Liu, H.-S.
  Microseismic low-frequency precursor effect of bursting failure of coal and rock
  (2012) *Journal of Applied Geophysics*, 79, pp. 55-63.
  2-s2.0-84862776923

- Chen, L., Guo, L.
  Discussions on the complete strain energy characteristics of deep granite and assessment of rockburst tendency
  (2020) *Shock and Vibration*, 2020, pp. 1-9.
  8825505

- Froemelt, A., Dürrenmatt, D.J., Hellweg, S.
  Using data mining to assess environmental impacts of household consumption behaviors
  (2018) *Environmental Science & Technology*, 52 (15), pp. 8467-8478.
  2-s2.0-85049246090

- Mahmood, A., Tang, X.-W., Qiu, J.-N., Gu, W.-J., Feezan, A.
  A hybrid approach for evaluating CPT-based seismic soil liquefaction potential using Bayesian belief networks
  (2020) *Journal of Central South University*, 27 (2), pp. 500-516.

- Ahmad, M., Tang, X.-W., Qiu, J.-N., Ahmad, F.
  Evaluating seismic soil liquefaction potential using bayesian belief network and C4.5 decision tree approaches
  (2019) *Applied Sciences*, 9 (20), p. 4226.
  2-s2.0-85074154802

- Ahmad, M., Tang, X., Qiu, J., Ahmad, F., Gu, W.
  LLDV-a Comprehensive Framework for Assessing the Effects of Liquefaction Land Damage Potential, pp. 527-533.
  Proceedings of the 2019 IEEE 14th International Conference on Intelligent Systems and Knowledge Engineering (ISKE) November 2019 Dalian, China

- Ahmad, M., Tang, X.-W., Qiu, J.-N., Ahmad, F., Gu, W.-J.
  A step forward towards a comprehensive framework for assessing liquefaction land damage vulnerability: Exploration from historical data
  (2020) *Frontiers of Structural and Civil Engineering*, 14 (6), pp. 1476-1491.

- Ahmad, M., Tang, X., Ahmad, F.
  Evaluation of liquefaction-induced settlement using random forest and REP tree models: Taking pohang earthquake as a case of illustration
  (2020) *Natural Hazards-Impacts*,
  IntechOpen Adjustments & Resilience

- Ahmad, M., Al-Shayea, N.A., Tang, X.-W., Jamal, A., Ahmad, F.
  Predicting the pillar stability of underground mines with random trees and C4.5 decision trees
  (2020) *Applied Sciences*, 10 (18), p. 6486.

- Ahmad, M., Kamiński, P., Olczak, P., Alam, M., Iqbal, M.J., Ahmad, F., Sasui, S., Khan, B.J.
  Development of prediction models for shear strength of rockfill material using machine learning techniques

(2021) *Applied Sciences*, 11 (13), p. 6167.

- Noori, A.M., Mikaeil, R., Mokhtarian, M., Haghshenas, S.S., Foroughi, M.
  Feasibility of intelligent models for prediction of utilization factor of TBM
  (2020) *Geotechnical & Geological Engineering*, 38 (3), pp. 3125-3143.

- Dormishi, A., Ataei, M., Mikaeil, R., Khalokakaei, R., Haghshenas, S.S.
  Evaluation of gang saws' performance in the carbonate rock cutting process using feasibility of intelligent approaches
  (2019) *Engineering Science and Technology, An International Journal*, 22 (3), pp. 990-1000.
  2-s2.0-85060700728

- Mikaeil, R., Haghshenas, S.S., Hoseinie, S.H.
  Rock penetrability classification using artificial bee colony (ABC) algorithm and self-organizing map
  (2018) *Geotechnical & Geological Engineering*, 36, pp. 1309-1318.
  2-s2.0-85039856937

- Mikaeil, R., Haghshenas, S.S., Ozcelik, Y., Gharehgheshlagh, H.H.
  Performance evaluation of adaptive neuro-fuzzy inference system and group method of data handling-type neural network for estimating wear rate of diamond wire saw
  (2018) *Geotechnical & Geological Engineering*, 36 (6), pp. 3779-3791.
  2-s2.0-85046647760

- Momeni, E., Nazir, R., Jahed Armaghani, D., Maizir, H.
  Prediction of pile bearing capacity using a hybrid genetic algorithm-based ANN
  (2014) *Measurement*, 57, pp. 122-131.
  2-s2.0-84906825852

- Xie, C., Nguyen, H., Choi, Y., Jahed Armaghani, D.
  Optimized functional linked neural network for predicting diaphragm wall deflection induced by braced excavations in clays
  (2022) *Geoscience Frontiers*, 13 (2), p. 101313.

- Armaghani, D.J., Mohamad, E.T., Narayanasamy, M.S., Narita, N., Yagiz, S.
  Development of hybrid intelligent models for predicting TBM penetration rate in hard rock condition
  (2017) *Tunnelling and Underground Space Technology*, 63, pp. 29-43.
  2-s2.0-85006990022

- Guido, G., Haghshenas, S.S., Haghshenas, S.S., Vitale, A., Gallelli, V., Astarita, V.
  Development of a binary classification model to assess safety in transportation systems using GMDH-type neural network algorithm
  (2020) *Sustainability*, 12 (17), p. 6735.

- Fiorini Morosini, A., Shaffiee Haghshenas, S., Choi, D.Y., Geem, Z.W.
  Sensitivity analysis for performance evaluation of a real water distribution system by a pressure driven analysis approach and artificial intelligence method
  (2021) *Water*, 13 (8), p. 1116.

- Asteris, P.G., Lourenço, P.B., Roussis, P.C., Elpida Adami, C., Armaghani, D.J., Cavaleri, L., Chalioris, C.E., Pilakoutas, K.

Revealing the nature of metakaolin-based concrete materials using artificial intelligence techniques
(2022) *Construction and Building Materials*, 322, p. 126500.

- Hajihassani, M., Jahed Armaghani, D., Sohaei, H., Tonnizam Mohamad, E., Marto, A.
Prediction of airblast-overpressure induced by blasting using a hybrid artificial neural network and particle swarm optimization
(2014) *Applied Acoustics*, 80, pp. 57-67.
2-s2.0-84893973238

- Guo, D., Chen, H., Tang, L., Chen, Z., Samui, P.
Assessment of rockburst risk using multivariate adaptive regression splines and deep forest model
(2021) *Acta Geotechnica*, 14, pp. 1-23.

- Li, D., Liu, Z., Armaghani, D.J., Xiao, P., Zhou, J.
Novel ensemble intelligence methodologies for rockburst assessment in complex and variable environments
(2022) *Scientific Reports*, 12 (1), pp. 1844-1923.

- Papadopoulos, D., Benardos, A.
Enhancing machine learning algorithms to assess rock burst phenomena
(2021) *Geotechnical & Geological Engineering*, 39 (8), pp. 5787-5809.

- Hong-Bo, Z.
Classification of rockburst using support vector machine
(2005) *Rock and Soil Mechanics*, 26, pp. 642-644.

- Chen, D., Feng, X., Yang, C., Chen, B., Qiu, S., Xu, D.
Neural network estimation of rockburst damage severity based on engineering cases
(2013) *Rock Characterisation, Modelling and Engineering Design Methods*, 6, pp. 457-462.

- Gong, F., Li, X.
A distance discriminant analysis method for prediction of possibility and classification of rockburst and its application
(2007) *Yanshilixue Yu Gongcheng Xuebao/Chinese Journal of Rock Mechanics and Engineering*, 26, pp. 1012-1018.

- Gong, F., Li, X., Zhang, W.
Rockburst prediction of underground engineering based on Bayes discriminant analysis method
(2010) *Rock and Soil Mechanics*, 31, pp. 370-377.

- Zhou, J., Shi, X.-X., Dong, L., Hu, H.-Y., Wang, H.-Y.
Fisher discriminant analysis model and its application for prediction of classification of rockburst in deep-buried long tunnel
(2010) *Journal of Coal Science and Engineering*, 16 (2), pp. 144-149.
2-s2.0-77953676476

- Zhou, J., Li, X., Shi, X.
Long-term prediction model of rockburst in underground openings using heuristic algorithms and support vector machines

(2012) *Safety Science*, 50 (4), pp. 629-644.
2-s2.0-84856475059

- Adoko, A.C., Gokceoglu, C., Wu, L., Zuo, Q.J.
Knowledge-based and data-driven fuzzy modeling for rockburst prediction
(2013) *International Journal of Rock Mechanics and Mining Sciences*, 61, pp. 86-95.
2-s2.0-84875244443

- Liu, Z., Shao, J., Xu, W., Meng, Y.
Prediction of rock burst classification using the technique of cloud models with attribution weight
(2013) *Natural Hazards*, 68 (2), pp. 549-568.
2-s2.0-84881051376

- Ge, Q., Feng, X.
Classification and prediction of rockburst using AdaBoost combination learning method
(2008) *ROCK and SOIL MECHANICS-WUHAN-*, 29, p. 943.

- Dong, L.-J., Li, X.-B., Peng, K.
Prediction of rockburst classification using Random Forest
(2013) *Transactions of Nonferrous Metals Society of China*, 23 (2), pp. 472-477.
2-s2.0-84875202057

- Liu, Q., Wang, X., Huang, X., Yin, X.
Prediction model of rock mass class using classification and regression tree integrated AdaBoost algorithm based on TBM driving data
(2020) *Tunnelling and Underground Space Technology*, 106, p. 103595.

- Pham, B.T., Nguyen, M.D., Nguyen-Thoi, T., Ho, L.S., Koopialipoor, M., Kim Quoc, N., Armaghani, D.J., Le, H.V.
A novel approach for classification of soils based on laboratory tests using Adaboost, Tree and ANN modeling
(2021) *Transportation Geotechnics*, 27, p. 100508.

- Pu, Y., Apel, D.B., Lingga, B.
Rockburst prediction in kimberlite using decision tree with incomplete data
(2018) *Journal of Sustainable Mining*, 17 (3), pp. 158-165.
2-s2.0-85055102833

- Zhao, H., Chen, B.
Data-Driven model for rockburst prediction
(2020) *Mathematical Problems in Engineering*, 2020, pp. 1-14.
5735496

- Ahmad, M., Hu, J.-L., Hadzima-Nyarko, M., Ahmad, F., Tang, X.-W., Rahman, Z.U., Nawaz, A., Abrar, M.
Rockburst hazard prediction in underground projects using two intelligent classification techniques: A comparative study
(2021) *Symmetry*, 13 (4), p. 632.

- Aliha, M.R.M., Ayatollahi, M.R.
Analysis of fracture initiation angle in some cracked ceramics using the generalized maximum tangential stress criterion

(2012) *International Journal of Solids and Structures*, 49 (13), pp. 1877-1883.
2-s2.0-84860728976

- Ryder, J.
Excess shear stress in the assessment of geologically hazardous situations
(1988) *Journal of the South African Institute of Mining and Metallurgy*, 88, pp. 27-39.

- Qian, Q., Huang, L.R.S.Y.
Enhanced resistance to blast fungus in rice (Oryza sativa L.) by expressing the ribosome-inactivating protein alpha-momorcharin
(2014) *Plant Science*, 217-218, pp. 1-7.
2-s2.0-84890298817

- Kidybiński, A.
Bursting liability indices of coal
(1981) *In Proceedings of International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts*, 18, pp. 295-304.

- Singh, S.P.
Burst energy release index
(1988) *Rock Mechanics and Rock Engineering*, 21 (2), pp. 149-155.
2-s2.0-0023996524

- Wang, Y., Li, W., Li, Q.
Fuzzy estimation method of rockburst prediction
(1998) *Chinese Journal of Rock Mechanics and Engineering*, 17, pp. 493-501.

- Freund, Y., Schapire, R., Abe, N.
A short introduction to boosting
(1999) *Journal of Japanese Society for Artificial Intelligence*, 14, p. 1612.

- Wang, G., Hao, J., Ma, J., Jiang, H.
A comparative assessment of ensemble learning for credit scoring
(2011) *Expert Systems with Applications*, 38 (1), pp. 223-230.
2-s2.0-77956619458

- Sakiyama, Y., Yuki, H., Moriya, T., Hattori, K., Suzuki, M., Shimada, K., Honma, T.
Predicting human liver microsomal stability with machine learning techniques
(2008) *Journal of Molecular Graphics and Modelling*, 26 (6), pp. 907-915.
2-s2.0-37349114485

- Landis, J.R., Koch, G.G.
An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers
(1977) *Biometrics*, 33 (2), pp. 363-374.
2-s2.0-0017381382

- Rezania, M., Faramarzi, A., Javadi, A.A.
An evolutionary based approach for assessment of earthquake-induced soil liquefaction and lateral displacement
(2011) *Engineering Applications of Artificial Intelligence*, 24 (1), pp. 142-153.
2-s2.0-78649656808

- Liang, W., Luo, S., Zhao, G., Wu, H.
  Predicting hard rock pillar stability using GBDT, XGBoost, and LightGBM algorithms
  (2020) *Mathematics*, 8 (5), p. 765.

- Russenes, B.
  (1974) *Analysis of Rock Spalling for Tunnels in Steep Valley Sides*,
  Norwegian Institute of Technology

- Zhou, J., Li, X., Mitri, H.S.
  Classification of rockburst in underground projects: Comparison of ten supervised learning methods
  (2016) *Journal of Computing in Civil Engineering*, 30 (5), p. 4016003.
  2-s2.0-84983252843

- Lin, Y., Zhou, K., Li, J.
  Application of cloud model in rock burst prediction and performance comparison with three machine learning algorithms
  (2018) *IEEE Access*, 6, pp. 30958-30968.
  2-s2.0-85048024540

- Tang, Z., Ding, J.C., Zhai, X.-X.
  Effects of resveratrol on the expression of molecules related to the mTOR signaling pathway in pathological scar fibroblasts
  (2020) *Giornale Italiano di Dermatologia e Venereologia*, 155 (2), pp. 161-167.

- Zhou, Y., Wang, T.
  PNN-based rockburst prediction model and its applications
  (2017) *Earth Sciences Research Journal*, 21 (3), pp. 141-146.
  2-s2.0-85030653739

Correspondence Address
Katman H.Y.; Institue of Energy Infrastructure, Jalan IKRAM-UNITEN, Malaysia; email: herda@uniten.edu.my

Publisher: Hindawi Limited

ISSN: 10762787
Language of Original Document: English
Abbreviated Source Title: Complexity
2-s2.0-85130610620
Document Type: Article
Publication Stage: Final
Source: Scopus