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Nikola Stanić[*], Miljan Gomilanović[*], Saša Stepanović[*], Aleksandar Milijanović[*]

OVERVIEW OF APPLICATION THE SOFT COMPUTING METHODS IN THE FIELD OF MINING IN OUR COUNTRY AND IN THE WORLD[**]

Abstract

Application of the Soft computing in the mining industry is of great importance. This paper shows only a part of the published scientific and professional articles on application the Soft Computing methods in our country and in the world in the field of mining. Originally, the Soft Computing methods arose from the need to analyze the complex processes and problems in a quick and simple way with relatively little knowledge of the influencing parameters. Considering that the mining problem is related to numerous and largely insufficiently investigated influential factors, the soft computing methods are widely applied in this area and their application leads to an improvement in understanding the mutual influence of natural and technical-technological factors in the processes of exploitation, selection and maintenance of the basic and auxiliary mining equipment, the impact of mining operations on the environment, social environment and other aspects of mining activities.

Keywords: *Soft computing, Fuzzy logic, ANN, mining*

INTRODUCTION

The Soft Computing (SC) represents a new and innovative approach to the construction of intelligent systems. By definition, the Soft Computing is an approach to computing that mimics the extraordinary ability of the human mind to conclude and learn in an environment of uncertainty and imprecision. [1]. The Soft Computing methods that are most widespread include: fuzzy logic and artificial neural networks, but the evolutionary algorithms, rough sets, decision trees methods are used less frequently, support vector machines, genetic algorithms are used less frequently.

The Soft Computing Techniques are a reliable tool to help in the design, development and operation of intelligent systems that have the ability to adapt, learn and act independently. In addition, these techniques allow the designer of the process model to take advantage of the knowledge accumulated in the system being modeled (in the form of linguistic or in the form of other data), to continuously learn from operational experience and to take advantage of the capabilities of intelligent algorithms for the process optimization [2]

[*] *Mining and Metallurgy Institute Bor, Zeleni Bulevar 35, 19210 Bor, Serbia, e-mail: nikola.stanic@irmbor.co.rs*

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The advantages and disadvantages of the most commonly used SC methods are given in Figure 1.

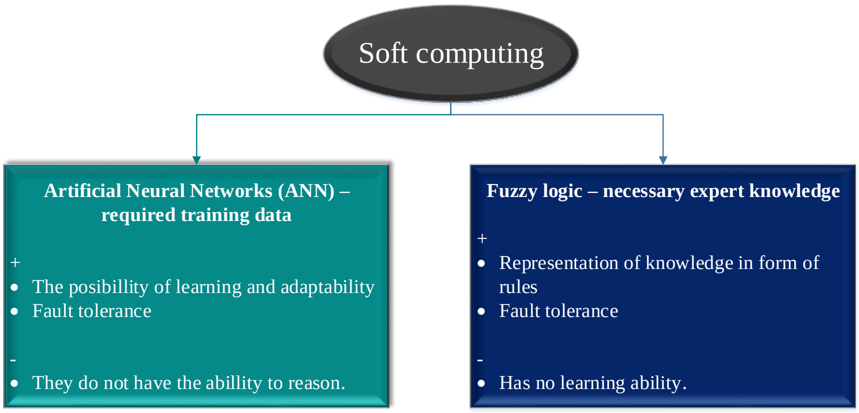

Figure 1 *Advantages and disadvantages of the SC methods*

LITERATURE REVIEW

In this review paper, the works with the application of Soft Computing in mining are presented. In recent years, the Soft Computing has been increasingly used in mining. The largest number of works is related to the process of blasting, the field of mechanization in mining, environmental impact assessment, etc. On the other hand, the application of numerous methods from the field of Soft Computing enables the aforementioned problem to be successfully analyzed, and the analysis results reflect the previous expert experiences and results of experimental measurements in a good way. To assess the success of the application of these methods, a prior knowledge of behavior the analyzed systems and processes is necessary. Its verification is performed by comparison the experienced and experimental data with the analysis results using one of the Soft Computing methods. Every specific issue isolated from a broad domain of mining, whether it is about the complex technical systems, natural or technological processes, can be analyzed using one of the Soft Computing methods, and most often, several methods can be applied to one problem or their mutual combination or combination with one of the other methods from the field of operational research. Furthermore, an overview of works in our country and in the world with the application of Soft Computing is presented.

In the paper entitled "Predicting the Availability of Continuous Mining Systems Using the LSTM Neural Network" [3] Gomilanovic M. and other authors deal with the development of a model for predicting the availability of continuous mining systems using the artificial neural networks. The idea of this paper is to improve the analytical approach for determining the availability of continuous systems. The data on which the model was developed are related to the I ECC system at the Open Pit Drmno Kostolac. The aim of this work is to improve the model for predicting the availability. Based on the values of test statistics *RMSE, MAE* and R^2 in this paper, it is concluded that the model obtained using an artificial neural network has a higher predictive power compared to the analytical approach. At the end of the work, a simulation is created showing the availability range of continuous coal system.

Gomilanović M. and other authors in the paper entitled "Determining the Availability of Continuous Systems at Open Pits Applying Fuzzy Logic" [4] present a model for determining the availability of continuous systems at the open pit using the fuzzy logic, fuzzy inference system. The applied model was formed on the basis of partial indicators of availability. This model is based on an expert system for assessment the availability of continuous systems at the Open Pit Drmno. Partial indicators that make availability are reliability and ease of maintenance. The Fuzzy compositions used for integration the partial indicators are the max-min and min-max compositions. This model for determining the availability has a role to help the responsible persons at the open pit in planning and controlling the exploitation, adopting the maintenance strategy, and all with the aim of stable production and cost reduction. The presented model can be used as a tool for rapid assessment the availability of the complex technical systems.

Ivezić D. and others, in the paper entitled "A Fuzzy Expert Model for Availability Evaluation" [5], analyze the availability concept of the mining machines. In this paper, an expert phase model was created that analyzes and integrates the reliability, convenience of maintenance and functionality of three types of bulldozers that work at the open pit within the Electric Power Company of Serbia. Based on the evaluation results, a comparison of bulldozers was made. In this paper, conclusions are given that can be useful for improving the convenience of maintenance, logistics and purchase the new machines.

Tanasijevic M. and others in the paper entitled "A Fuzzy-Based Decision Support Model for Effectiveness Evaluation - A Case Study of the Examination of Bulldozers" [6] define the effectiveness as a comprehensive concept and measure of the usability level of the observed technical system. This paper presents the analysis and structuring of partial indicators. A model has been developed for their synthesis to the level of effectiveness. The paper used indicators of a hybrid nature, such as the measured values and expert evaluations. A phased reasoning model for their processing and integration into effectiveness is presented. This concept enabled the evaluation of technical system in terms of making decisions about the remaining possibilities and optimizing the life cycle costs. The efficiency evaluation model is applied on an example of bulldozer auxiliary machines. In this paper, two approaches are given. The first approach is based on the expert evaluations, and the second approach is based on the measurement and statistical data processing.

In the paper entitled "Study of Dependability Evaluation for Multi-hierarchical Systems Based on MaxMin Composition" [7] Tanasijević M. et al. present a model of safety of functioning the complex technical systems that includes the partial indicators of reliability, convenience of maintenance and logistic support for maintenance. Partial indicators of safety of functioning are defined as linguistic variables. In this work, the max-min composition was applied to determine the safety of functioning. A concept for synthesis the performance safety of the functioning of individual components in a complex technical system is proposed.

In the paper entitled "Multi-criteria Approach for Selecting Optimal Dozer Type in the Open-Cast Coal Mining" by Janković I. et al. [8], an analysis of the availability and lifetime costs of dozers is provided. The parameters taken into analysis in this work are as follows: technical, economic, exploitation and survey. Since tthe calculated data are not mutually measurable (more precisely, they cannot be compared with each other), a mathematical method with the multi-criteria approach AHP (method of analytical hierarchical processes) was used. In addition to the fact that it is a traditional method, the authors have shown that it is possible to reach results that show their advantages and disadvantages when choosing mechanization through the multi-attribute consideration. The presented method showed that with a minor adjustment of the parameters, it can be applied to all auxiliary machines.

In the paper entitled "Adaptive Neuro-Fuzzy Prediction of Operation of the Bucket Wheel Drive Based on Wear of Cutting Elements" by the author Miletić F. et al. [9], a model made as a combination of artificial neural networks and fuzzy logic, so-called the ANFIS (Adaptive Neuro Fuzzy Inference System) is presented. The main goal of this work is to determine the dependence of how the wear of the cutting elements affects the operation of rotary excavator drive.

In the paper entitled "Applying the Fuzzy Inference Model in Maintenance Centered to Safety: Case Study - Bucket Wheel Excavator" by Jovančić P. et al. [10] the safety-focused maintenance according to the adaptive fuzzy inference model is promoted, which has online adaptation to operating conditions. The input parameters for this model are indicators of the service quality of the analyzed engineering system: reliability, maintainability, consequence, severity and observability of fai-lures.

In the paper entitled "A Hybrid Artificial Bee Colony Algorithm-Artificial Neural Network for Forecasting the Blast-Produced Ground Vibration" [11] by Taheri K. et al., a hybrid model for predicting the explosion-induced ground vibrations is presented in the Miduk copper mine Iran using a combination of the artificial neural network with the ABC (artificial bee colony). The predicted values of ground vibration using this model were compared with several empirical models. Model results were compared with the available data using the mean absolute percentage error, root mean squared error and coefficient of correlation R^2.

Wang J., Yang JB. and Sen P. in the paper entitled "Safety Analyzes and Synthesis Using Fuzzy Sets and Evidential Reasoning" [12] provide a methodology for safety analysis the complex engineering system with a structure that can be decomposed into hierarchical levels. This methodology uses the fuzzy logic to describe each failure, and then the fuzzy inference is used to synthesize the information thus obtained to assess the safety of the entire system. The parameters of failure probability, failure severity and failure consequence probability are used for the failure analysis. These parameters are described by the linguistic variables, characterized by the function of belonging to the defined categories. In this paper, a practical engineering example is given that shows the proposed safety analysis and synthesis methodology.

Das A. et al., in the paper entitled "Development of a Blast-Induced Vibration Prediction Model Using Artificial Neural Network" [13], develop an ANN model for the blast vibration prediction using the 248 data records collected from three coal mines with different blasting conditions. It was found that the correlation coefficient between the measured peak particle velocity (PPV) and the output of model is 0.96, and the average error percentage is 11.85. The output of the ANN model was compared with the output of three empirical models widely used to predict the PPV. The correlation coefficient between the PPV predicted by the empirical model and the measured PPV data was 0.63, and the relative error percentage was 38.47. This result shows the superiority of the ANN model compared to the empirical models.

Khandelwal M. et al., in the paper entitled "Application of Soft Computing to Predict Blast-Induced Ground Vibration" [14] provide an assessment of the ground vibration using the ANN (artificial neural network). The neural network architecture consists of 3 layers. The first layer or input layer consists of 2 neurons, the second layer or hidden layer consists of 5 neurons and the third output layer has one neuron. For training and testing, the 130 records were used at the Singareni Collieries Open Pit Coal Mine of Kothagudem, Andhra Pradesh, India. The 20 new records were used for validation. The results were compared on the basis of determination coefficient and mean absolute error between the monitored and predicted PPV (peak particle velocity) values.

When it comes to the application of artificial neural networks in the modeling of flotation processes, Al-Thyabat considered the effect of three input parameters (mean grain diameter in the input pulp, collector dose and flotation machine impeller rotation speed) on utilization and quality of the concentrate obtained by the process of flotation concentration of Jordanian phosphates. For this purpose, the author studied the suitability of different architectures of multilayer perceptrons and came to the conclusion that the most suitable network architecture is [3-9-11-5-9-2] (with 4 hidden layers), giving the smallest mean square error. The results of simulations realized using the ANN showed that the optimal utilization and quality of concentrate are 92.97% and 83.47%, respectively. The optimal values of parameters that give the mentioned results are: mean grain diameter 321.28 μm; collector consumption 735.4 g/t and impeller speed 1225.25 min^{-1}[15].

Lal B. et al., in the paper entitled "Prediction of Dust Concentration in Open Cast Coal Mine Using Artificial Neural Network" [16] developed 3 models for predicting the concentration of dust particles at different locations far from the pollution source. These models were developed using the Multilayer Perception Network and learning was performed with the help of back-propagation algorithm. Data for training and testing the network were collected in the field at the Karanpura coal mine, Jharkhand in India. The following are used as inputs in these models: meteorological data (wind speed, dispersion coefficients, precipitation, cloudiness and temperature), geographic data and emission rate. Each model has a different number of inputs, and the output (dust concentration) is the same for all three models. Based on the performance of all three models, it was concluded that the model number 3 is better than the models 1 and 2.

Petrović D. et al., in the paper entitled "Fuzzy Model for Risk Assessment of Machinery Failures" [17] provide an algorithm for implementing the negative risk parameters into a synthesis model for assessing the risk level of machinery used in mining. Fuzzy logic theory in combination with the statistical method was applied to analyze the time image of the state of the observed machine. Fuzzy logic is represented through the fuzzy proposition and fuzzy composition models. Using these tools, the symmetric fuzzy sets were applied in relation to the classes and fuzzy inference in the calculation outcome. The convenience of the proposed model is the possibility of using numerical and linguistic data in the risk assessment model. The proposed risk assessment model, using the fuzzy logic inference and min-max composition, was applied to the Lokotrack LT 1213S mobile crusher of the Open Pit Ladna Voda in Petrovac on Mlava.

In the paper entitle "Fuzzy Expert Analysis of the Severity of Mining Machinery Failure" Petrović D. et al. [18] show the concept of failure severity analysis, one of the risk indicators. The consequences are observed through the negative effects that dismissal has on a machine, the health and safety of the employees, working environment and environment. Repairing the consequences of dismissal requires the additional financial investment, which negatively affects the company operations. In order to prevent this, it is necessary to introduce a risk-based maintenance policy, where the risk assessment would include all the negative consequences of a risky event. A phased expert model of failure severity assessment, based on the harmful effects of failure, is proposed. The negative effects of machine failure were analyzed, such as the time required for repair, possibility of injury at the workplace as a result of t failure, and impact of failure on the environment. This approach to the assessment the severity of failure allows a comprehensive insight into this risk indicator. The model was applied on an example of failure of hydraulic subsystems of a mobile crusher "Lokotrack LT1213S" of the Open Pit Ladna Voda.

CONCLUSION

The positive trend in application the soft computing methods in the field of mining recently indicates the broad possibilities of analyzing various technical, technological, chemical, physical and other processes, as well as complex technical and natural systems. With the increase in application of these methods, better planning, design, prediction of system behavior and optimization of process parameters are possible. On the other hand, some of the methods are more often applied in this area compared to the others. Thus, the application of Fuzzy logic is the most present in the analyzed papers, followed by the application of the method of artificial neural networks, while the others are significantly less present. Among the less frequently applied, hybrid methods are the most represented, which try to reduce the influence of negative features of the soft computing methods.

The mentioned soft computing methods are equally successfully applied to both simple and complex technical systems and to the technical-technological processes from exploitation, through the processing of mineral raw materials to modeling the impact of mining operations on the environment. This characteristic distinguishes soft computing methods as methods that will be increasingly applied in the future, especially in the complex conditions of mine-environment interaction, technical system-maintenance and technological system-parameter optimization. The main advantage of application of these methods, apart from the possibility of wide application, is that the analysis can be carried out in conditions when the influencing parameters cannot be precisely determined or not all important parameters that influence the behavior or the relationship between different systems can be identified.

REFERENCES

[1] Jang, H. and Topal, E. 2014. A Review of Soft Computing Technology Applications in Several Mining Problems. Applied Soft Computing. 22: pp. 638-651. https://doi.org/10.1016/j.asoc.2014.05.019

[2] Karray, F., De Silva, C., 2004. Soft Computing and Intelligent Systems Design. Publisher: Pearson Education, 560 p. https://doi.org/10.1002/rnc.1072

[3] Gomilanovic M, Stanic N, Milijanovic D, Stepanovic S, Milijanovic A. Predicting the availability of continuous mining systems using LSTM neural network. Advances in Mechanical Engineering. 2022;14(2). doi:10.1177/16878132221081584

[4] Gomilanovic, M.; Tanasijevic, M.; Stepanovic, S. Determining the Availability of Continuous Systems at Open Pits Applying Fuzzy Logic. Energies 2022, 15, 6786. https://doi.org/10.3390/en15186786

[5] Ivezic D.; Tanasijević M.; Jovancic P.; Djuric, R. A Fuzzy Expert Model for

Availability Evaluation. In Proceedings of the 20th International Carpathian Control Conference (ICCC), Kraków-Wieliczka, Poland, 26–29 May 2019; ISBN 978-1-7281-0701-1. doi:10.1109/CarpathianCC.2019.8766031

[6] Tanasijevic, M., Jovancic, P., Ivezic, D., Bugaric, U., & Djuric, R. (2020). A fuzzy-Based Decision Support Model for Effectiveness Evaluation – A Case Study of Examination of Bulldozers. International Journal of Industrial Engineering: Theory, Applications and Practice, 26(6). https://doi.org/10.23055/ijietap.2019.26.6.3304

[7] Tanasijević Miloš, Ivezić Dejan, Jovančić Predrag, Ćatić Dobrivoje, Zlatanović D.. Study of Dependability Evaluation for Multi-hierarchical Systems Based on Max–Min Composition, Quality and Reliability 18, 4 (2013): 317-326. https://doi.org/10.1002/qre.1383

[8] Jankovic I, Djenadic S, Ignjatovic D, Jovancic P, Subaranovic T, Ristovic I. Multi-Criteria Approach for Selecting Optimal Dozer Type in Open-Cast Coal Mining. Energies. 2019; 12(12):2245. https://doi.org/10.3390/en12122245

[9] Miletic, F., Jovancic, P., Milovancevic, M., & Ignjatovic, D. (2020). Adaptive Neuro-Fuzzy Prediction of Operation of the Bucket Wheel Drive Based on Wear of Cutting Elements. Adv. Eng. Softw., 146, 102824. doi: 10.1016/j.advengsoft.2020.102824

[10] Jovancic, P.; Tanasijevic, M.; Milisavljevic, V.; Cvijetic, A.; Ivezic, D.; Bugaric, U. Applying the Fuzzy Inference Model in Maintenance Centered to Safety: Case Study—Bucket Wheel Excavator. In Applications and Challenges of Maintenance and Safety Engineering in Industry 4.0; IGI Global: Hershey, PA, USA, 2020. doi: 10.4018/978-1-7998-3904-0.ch009

[11] Taheri, K., Hasanipanah, M., Golzar, S.B. et al. A Hybrid Artificial Bee Colony Algorithm-Artificial Neural Network for Forecasting the Blast-Produced Ground Vibration. Engineering with Computers 33, 689–700 (2017). https://doi.org/10.1007/s00366-016-0497-3

[12] J. Wang, J.B. Yang, P. Sen, Safety Analysis and Synthesis Using Fuzzy Sets and Evidential Reasoning, Reliability Engineering & System Safety, Volume 47, Issue 2, 1995, Pgs. 103-118, ISSN 0951-8320, https://doi.org/10.1016/0951-8320(94)00053-Q.

[13] Das A, Sinha S, Ganguly S. Development of a Blast-Induced Vibration Prediction Model Using an Artificial Neural Network. Journal South African Institute of Mining and Metallurgy 2019; 119: 187–200. doi: 10.17159/2411-9717/2019/v119n2a11

[14] Khandelwal M, Lalit Kumar D, Yellishetty M. Application of Soft Computing to Predict Blast-Induced Ground Vibration. Engineering with Computers, 2011; 27: 117–125. doi: 10.1007/s00366-009-0157-y

[15] Al-Thyabat, S., 2008. On the Optimization of Froth Flotation by the Use of Artificial Neural Network. Journal of China University of Mining and Technology 18 (3), pp. 418–426, https://doi.org/10.1016/S1006-1266(08)60087-5

[16] Lal B, Tripathy SS. Prediction of Dust Concentration in Open Cast Coal Mine Using Artificial Neural Network. *Atmospheric Pollution Research* 2012; 3: 211–218.
https://doi.org/10.5094/APR.2012.023

[17] Petrović D.V, Tanasijević M, Stojadinović S, Ivaz J, Stojković P. Fuzzy Model for Risk Assessment of Machinery Failures. Symmetry. 2020; 12(4):525.
https://doi.org/10.3390/sym12040525

[18] Petrović D. V, Tanasijević M, Stojadinović S, Ivaz J, Stojković P. Fuzzy Expert Analysis of the Severity of Mining Machinery Failure. Applied Soft Computing, Volume 94, 2020, 106459,
https://doi.org/10.1016/j.asoc.2020.106459