Hindawi
Advances in Civil Engineering
Volume 2018, Article ID 7813931, 6 pages
https://doi.org/10.1155/2018/7813931

Research Article

Probabilistic Prediction of Mine Dynamic Disaster Risk Based on Multiple Factor Pattern Recognition

Tianwei Lan[1,2,3] **Chaojun Fan**[1,4] **Sheng Li**[1,2,3] **Hongwei Zhang**[1] **and Andrian Sergaevich Batugin**[3,5]

[1] *College of Mining, Liaoning Technical University, Fuxin 123000, China*
[2] *State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology, Xuzhou 221000, China*
[3] *Research Center of Safe Exploitation and Clean Utilization Engineering of Coal Resources, Liaoning Technical University, Fuxin 123000, China*
[4] *State Key Laboratory Cultivation Base for Gas Geology and Gas Control, Henan Polytechnic University, Jiaozuo 454003, China*
[5] *Moscow Mining Institute, National Research University of Process Technology (MISIS), Moscow 119991, Russia*

Correspondence should be addressed to Chaojun Fan; chaojunfan@139.com

Received 18 September 2018; Accepted 23 November 2018; Published 18 December 2018

Guest Editor: Ray R. Zhang

Rock burst and coal and gas outburst are the most serious dynamic disasters in coal mine and are affected by many factors, such as mining engineering environment. In order to accurately predict the risk area of mine dynamic disasters, a series of impact factors and events are classified, and the spatial data of these factors are managed on the basis of identifying the internal relationship between the impact factors and the disasters. A multifactor pattern recognition model is established by artificial intelligence. The risk probability prediction criteria of mine dynamic disasters and the risk probability values of each unit in the prediction area are determined by using the method of neural network and fuzzy mathematics. The dangerous area, threat area, and safety area of mine dynamic disasters are divided to evaluate the dangerous degree. The corresponding control measures for different dangerous areas are also put forward. Application of the prediction method of mine dynamic disaster factors based on pattern recognition, to improve the implementation of mine dynamic disaster prediction and controlling measures, guarantees the safe production of the coal mine.

1. Introduction

The practice of coal mining at home and abroad shows that the dynamic disasters such as rock burst and coal and gas outburst are distributed regionally, accounting for 20%–25% of the whole mining area [1–6]. Many scholars investigated the dynamic disasters and carried out various measures to predict and prevent them [7–10]. The occurrence of coal mine dynamic disaster is the result of many factors, such as physical and mechanical properties of coal and rock, ground stress, elastic energy, geological structure, roof lithology, gas, and other factors [11–20]. Dynamic disasters under the condition of different mining areas, mines, coal seams, geology structures, and geostresses have different patterns; although the accurate prediction of events in time and place is more difficult, it is possible to predict the possibility size of this event (probability) [21].

Pattern recognition is the use of computers to classify a series of processes or events in the condition of minimum error rate; the automatic recognition mode, which is assigned to the respective class to make consistent recognition results and objective conditions, is an important part of information science and artificial intelligence [22–25]. A study on the theoretical analysis is carried out to find out the influence of multiple factors and dynamic hazard relationship based on the prediction of mine dynamic disasters with multiple factor pattern recognition probability, recognition model and pattern recognition criterion, research design and algorithm of pattern recognition system, and the development of mine dynamic disaster risk prediction system [26, 27]. On the basis of spatial data management, the probability prediction map of the mine area unit is established and the dangerous area, threat area, and safety zone of mine dynamic disaster are divided, and the risk is evaluated and corresponding control measures are put forward [28]. Prediction of multiple factor pattern recognition probability of mine dynamic disasters is the successful application of the method and provides a basis for mine dynamic disaster detection and controlling, to improve the implementation of mine dynamic disaster prediction and controlling measures and guarantee the safe production of the coal mine [29].

2. Multiple Factor Pattern Recognition of Mine Dynamic Disaster Risk Prediction

2.1. Principle of Multiple Factor Pattern Recognition for Mine Dynamic Disaster. The mechanism of mine dynamic disaster is complex and has many influencing factors. It is controlled by stress, active structure, gas pressure, coal structure, and so on. Take the *N*-factor study and consider each factor as a vector element, then the *N* factor forms an *N*-dimensional vector. Each combination of *N* factor is a pattern and only corresponds to one position in the *N*-dimensional feature space. Similar patterns are very close in feature space, and the patterns of different classes are far apart. The task of pattern recognition is to divide the feature space in some way so that the same pattern is located in the same area [30].

The process of multifactor pattern recognition of mine dynamic disasters is as follows: the intrinsic relationship between factors and dynamic disasters is first identified, then various factors and events are classified by computer, and finally the research area is divided into a number of prediction units to determine the magnitude of each factor on the basis of the spatial data [31, 32]. The multifactor pattern recognition technology is used to analyze comprehensively and intelligently the area where the mine dynamic disasters have occurred, and by this, the prediction pattern is determined. The risk probability of the dynamic disaster of each unit in the unexploited prediction area is obtained via comparing and analyzing the multifactor combination pattern of the unexploited area with the pattern of the occurred disaster area. According to the critical value of risk probability, the dangerous area, threatening area, and safety area are divided.

2.2. Algorithm of Multiple Factor Pattern Recognition for Mine Dynamic Disaster. The multiple factor model of mine dynamic disaster can be expressed by a feature set and also can be expressed as the feature vector of the same feature space. Then, the different models of mine unexplored areas to be identified in the same feature space and the feature range of characteristic parameters of the different effects of different factors will appear in the feature space in different regions. The multiple factor model sample of mine dynamic disaster has an *N*-variable (characteristic), which can be expressed by a vector, and the sample vector is random; therefore, $x = (x_1, x_2, \ldots, x_{\mathrm{n}})$ (Table 1).

Table 1: Sample vector representation of the occurrence pattern of mine dynamic disaster.

Sample	Variable			
	x_1	x_2	$\cdots$	x_n
x_1	x_{11}	x_{12}	$\cdots$	x_{1n}
x_2	x_{21}	x_{22}	$\cdots$	x_{2n}
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
x_n	x_{n1}	x_{n2}	$\cdots$	x_{nn}

In the multiple factor pattern recognition research of mine dynamic disaster, distance similarity is the most commonly used, and the Euclidean distance between model sample vectors *x* and *y* is defined as the Euclidean distance:

$$D_e(x, y) = \|x - y\| = \sqrt{\sum_{i=1}^{d} \left|x_i - y_i\right|^2}, \tag{1}$$

where D is the dimension of the feature space.

It represents X and Y in a type region.

Multiple factor pattern recognition of mine dynamic disaster refers to feature selection and extraction of vector data as training samples in the determined feature space so as to obtain their distribution in feature space. For a pattern sample, it corresponds to a point in the feature space. When appropriate pattern features are selected, similar samples will be distributed in the same region. On the contrary, different types of pattern samples will be far away and distributed in other regions. Therefore, the multifactor pattern recognition method can predict the risk of mine dynamic disasters. There are different models for mine dynamic disasters in different mining areas, mines, coal seams, structures, and stress conditions, and the risk areas have different characteristics.

2.3. Multiple Factor Pattern Recognition of Mine Dynamic Disaster Risk Prediction. Risk prediction of mine dynamic disaster first divides the prediction area into a limited number of units and then compares the "calculated pattern" in the specified unit with the pattern of the occurred dynamic disaster (memory pattern), to obtain the risk probability. The critical value of risk probability is determined by statistical analysis. The predicted area is divided into dangerous area and dangerous area and non-dangerous area (Figure 1). The accuracy of mine dynamic disaster prediction is improved.

3. Multiple Factor Pattern Recognition Visualization System for Mine Dynamic Disaster Risk Prediction

The multiple factor pattern recognition system for prediction of mine dynamic hazard is the visualization of information based on GIS technology, the relationship between the basic factors and disaster *n* affecting identification of mine dynamic disasters, the use of computer artificial intelligence pattern recognition software system and the mine dynamic disaster prediction system integrated with the data processing process automation, the establishment of rules and procedures, by

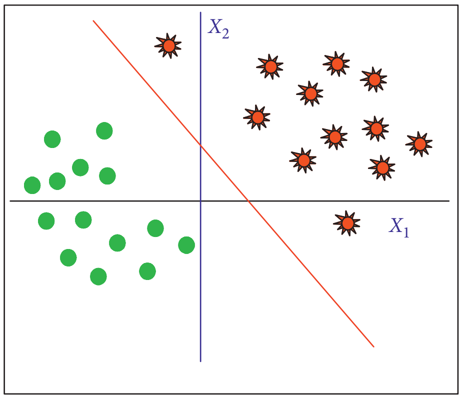

Figure 1: Determination of critical value of mine dynamic disaster risk and division of dangerous area.

inference, and the start execution module to implement the rules.

To allow the computer to complete the recognition task, the information input to the computer must first be classified in object recognition, scientific classification of abstract objects, initial operation procedures—first by the sample data preprocessing module made by the training sample library—learning module to produce classification, and start regional prediction identification module identification analysis (Figure 2).

Application of the multiple factor pattern recognition prediction system of risk probability can directly display the position of the corresponding relationship between the mine dynamic hazard distribution and mining roadway engineering; the method describes the quantitative prediction of mine dynamic disasters, and can clearly display the risk probability of each grid value (Figure 3).

4. Study on Risk Prediction of Rock Burst Happened in a Coal Mine of China

4.1. In Situ Case of Rock Burst. The average mining depth of coal mine in China is 800–1000 m, and the deepest depth has reached to 1080 m. With the increase of mining depth, mine dynamic disasters occur frequently with high strength. Severe rock burst phenomena occurred during the mining process after the mining entered the deep mining area. Since the record of rock burst, 24 rock burst phenomena have occurred, with magnitude $M_L = (0.5\text{–}3.0)$. Among them, the rock burst, occurred on June 19, 2007, has damaged the roadway about 500 m and rushed out 3700 m^3 of coal, resulting in casualties and damages of roadways and equipment. It has a serious threat to the safety of mine production.

Application of multiple factor pattern recognition prediction method of risk probability, the main effect of mine dynamic disasters including investigation, mining depth and geological structure (folds and faults), stress, mechanical property of coal seam, roof lithology, and the influence factors for the N class model, established the mine dynamic disaster risk factors pattern recognition probability prediction model (Figure 4).

4.2. Risk Zoning of Rock Burst. According to the size of the mining field, a calculate model is established. The model is 7.5 km in length and 5.5 km in width with about 41.25 km^2 in area. Based on this model, the application of multiple factor pattern recognition method to forecast scope of mine area is divided into 50 m × 50 m grid unit 9506; each unit grid corresponding the risk probability value of rock burst is solely according to statistics, with 0.43 and 0.66 as the critical values of risk classification, less than 0.43 for the safety zone and more than 0.66 for the danger zone. Threatening area between the two and the final forecast of mine area is divided into dynamic hazard zone (29%), the threatened area (35%), and the safety zone (36%), respectively, the risk degree of each color represents region (Figure 5).

4.3. Mine Dynamic Disaster Prevention and Control Technology. Prevention technology of dynamic disaster in coal mine is a prerequisite for regional prediction. In practical work, according to the risk probability values of different locations, regional measures are first selected to eliminate the risk. If conditions do not permit, the appropriate local measures are then adopted to reduce the risk. Local detection methods are adopted to determine whether the following mining activities can be carried out or more intensive safety measures should be strengthened. Among them, the corresponding prevention measures are adopted for different risk grades. According to the prediction results of multifactor pattern recognition and risk classification of mine rock burst risk, the corresponding prevention and control measures are as follows:

(1) Dangerous area of rock burst ($0.66 \le k < 1.0$). Take regional governance and local relief measures to detect the effect of prevention measures and strengthen the monitoring of mine dynamic disasters.

(2) Threat area of rock burst ($0.43 \le k < 0.66$). It should take local relief measures in the rock burst threat area. In the operation, we should strengthen the detection of dangerous state and carry out the mining operation under the safe condition.

(3) Safety area ($0 \le k < 0.43$). The normal mining work can be carried out according to the operation rules.

5. Conclusion

(1) The multiple factor pattern recognition probability prediction method to realize the mine dynamic hazard prediction from prediction to regional prediction, from single factor to the multiple factor prediction, and from qualitative to quantitative prediction of prediction direction, improves the accuracy of prediction of mine dynamic hazard.

(2) Based on the GIS technology, on the basis of finding out the influence factors and their relations of mine dynamic disasters, we use computer artificial intelligence to establish the

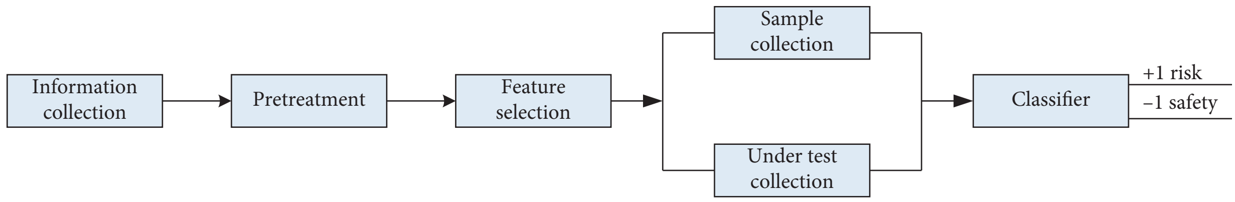

Figure 2: Design of mine dynamic disaster pattern recognition system.

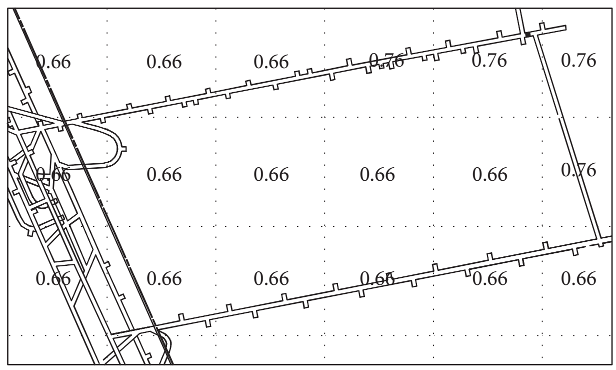

Figure 3: Relationship of hazard location between mining tunnel and unit mesh.

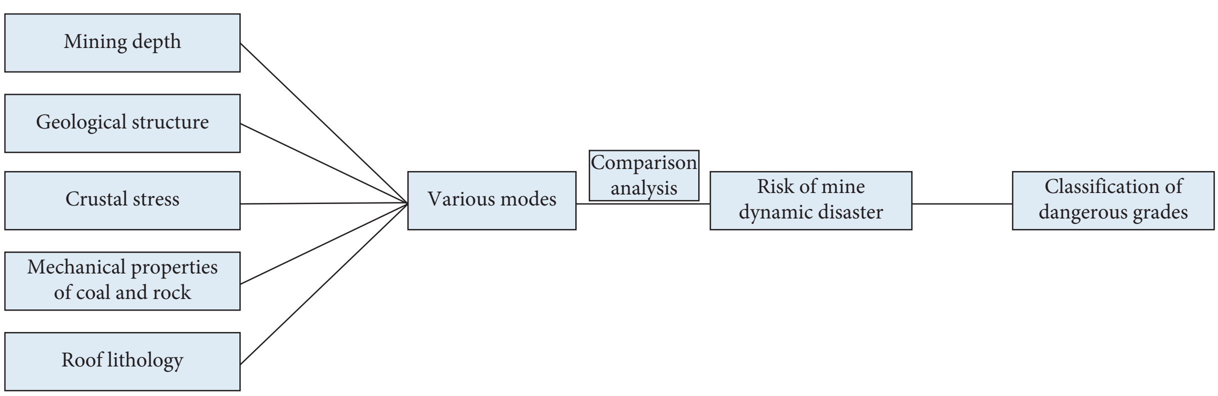

Figure 4: Multiple factor pattern recognition prediction model of dynamic disaster risk in a mine in China.

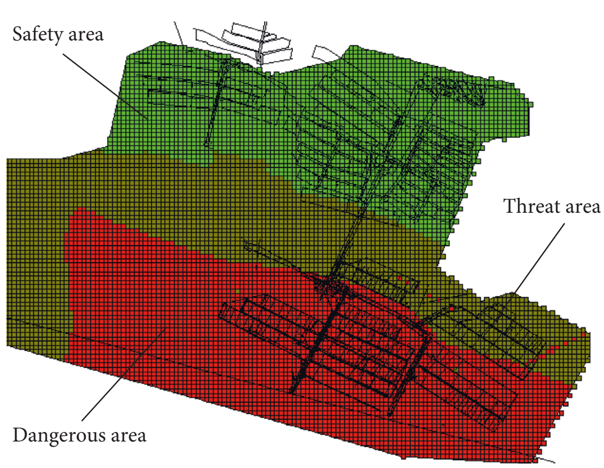

Figure 5: Regional division of mine dynamic disaster risk prediction.

multiple factor pattern recognition model and probability prediction rule and determine the probability of the prediction area units. Multiple factor pattern recognition probability prediction method improves the level of mine dynamic disaster risk area prediction.

(3) The multiple factor pattern recognition method can be applied to predict the risk probability of dynamic disasters in situ and to divide the studied area into the danger zone, threatened zone, and safe zone. By this, risk probability at the location of mining activities can be determined in advance, and the corresponding control measures are taken in advance. These can reduce the risk degree of dynamic disaster and guarantee the safety of the mining operation.

Data Availability

The experimental data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Acknowledgments

This research was funded by the State Key Research Development Program of China (Grant nos. 2016YFC0801407-2); the National Natural Science Foundation of China (51674132 and 51604139); the Research Fund of State Key Laboratory of Coal Resources and Safe Mining, CUMT (SKLCRSM18KF000); the Research Fund of State Key Laboratory Cultivation Base for Gas Geology and Gas Control (Henan Polytechnic University) (Grant no. WS2018B05); the Project of Education Department of Liaoning Province (No. LJYL037); the Open Projects of Research Center of Coal Resources Safe Mining and Clean Utilization, LNTU (LNTURCCRSMCU15KF09); and the Basic Research Project of Key Laboratory of Liaoning Provincial Education Department (Grant no. LJZS004).

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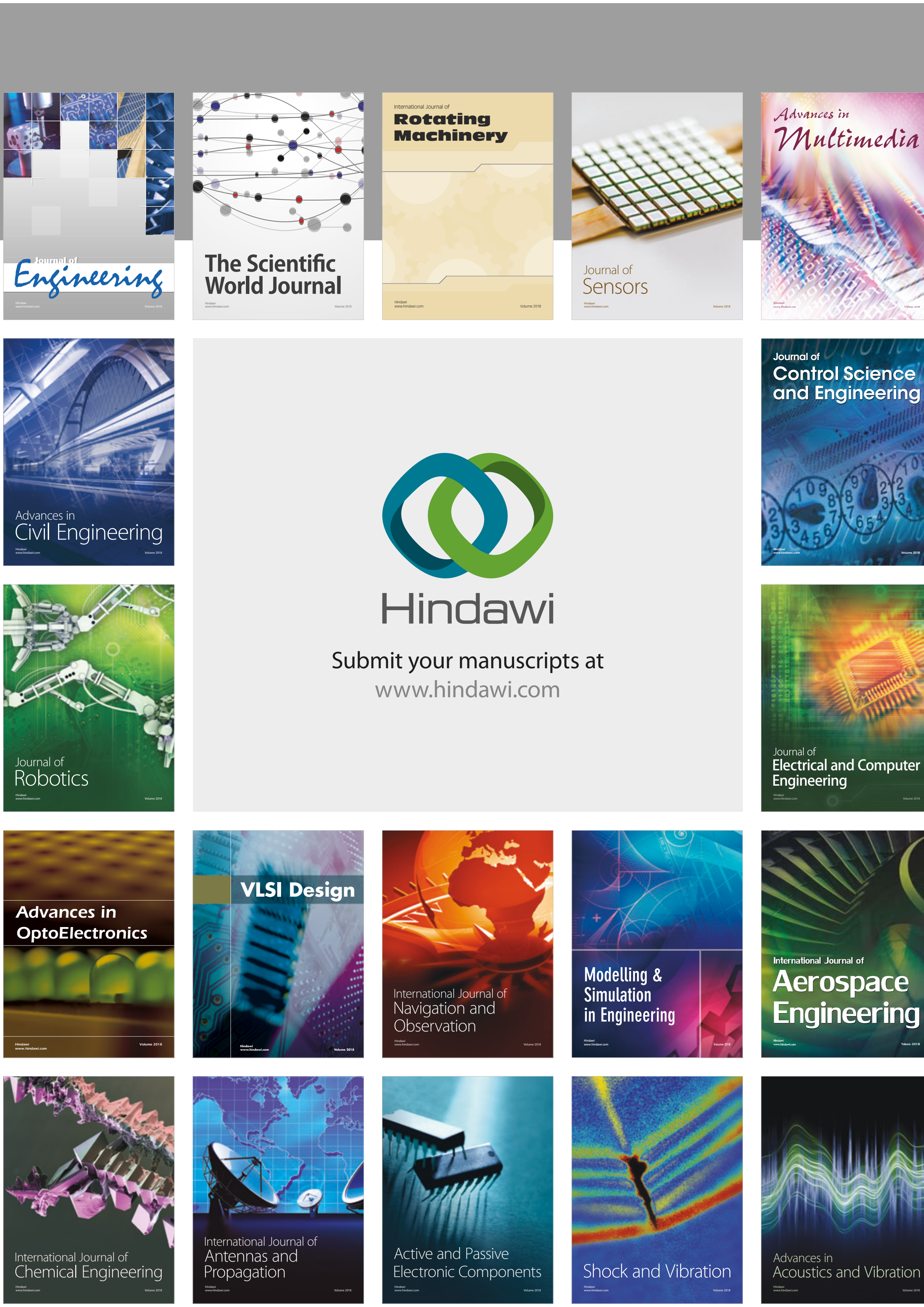

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